THE CHEMISTRY, DISPERSION AND TRANSPORT
OF AIR POLLUTANTS EMITTED FROM
FOSSIL FUEL POWER PLANTS

MOVING LABORATORY SUPPORT
FOR PLUME ANALYSIS

FINAL REPORT

ARB CONTRACT NO. 4-189

EMI PROJECT NO. 100

PREPARED FOR:

CALIFORNIA STATE AIR RESOURCES BOARD

SACRAMENTO, CALIFORNIA

PREPARED BY:

ENVIRONMENTAL MEASUREMENTS, INC.

SAN FRANCISCO, CALIFORNIA

4 APRIL 1975

ABSTRACT

Environmental Measurements, Inc. provided an Air Quality
Moving Laboratory for six days of data collection in the vici-
nities of the Moss Landing and the Haynes/Los Alamitos power
generating stations in California.

The purpose of the field measurements was to locate and
trace overhead plumes and measure ground-level impact of SO_2
and NO_x as a supplement to aerial and fixed station measure-
ments. The correlation spectrometer and point monitors were
used to map the dispersal of emissions from the target sour-
ces.

Downwind plume detection at Moss Landing was limited to
18 kilometers by gusty winds. Measurements at Haynes/Los
Alamitos produced more comprehensive results; plume transport
and touchdown were detected as far as 45 kilometers.

The results of the measurements are presented in map
form. The maps offer a graphic correlation between overhead
plume activity and ground-level impact.

Calculations of SO_2/NO_2 emission rates, plume path maps,
and ground-level data comparisons are included as examples of
data analyses.

This report was submitted in fulfillment of Contract No.
4-189 by Environmental Measurements, Inc. under the sponsor-
ship of the California State Air Resources Board. Work was
completed 4 April 1975.

DISCLAIMER

The statements and conclusions in this report
are those of the Contractor and not necessarily
those of the State Air Resources Board. The
mention of commercial products, their source
or their use in connection with material re-
ported herein is not to be construed as either
an actual or implied endorsement of such pro-
ducts.

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Section 1

INTRODUCTION

PURPOSE

The State of California Air Resources Board (ARB) invited Environmental Measurements, Inc. (EMI) to participate in a study of "The Chemistry, Dispersion and Transport of Air Pollutants Emitted from Fossil Fuel Power Plants". The purpose of the field measurements (ARB Contract No. 4-189) was to use a moving laboratory to locate overhead plumes and measure ground-level impact as a supplement to aerial and ground station measurements. Other contractors were: Meteorology Research Inc. (MRI), Rockwell International Science Center (RISC), California Institute of Technology (CIT), the California Department of Health, the Air and Industrial Hygiene Laboratory (AIHL) and Systems Applications Inc. (SAI). The remote sensor located the overhead SO_2/NO_2 plume near the source; as the moving laboratory proceeded downwind the point monitors detected increased ground-level gas concentrations (depending on meteorological conditions) while the remote sensor continued to locate the remaining portion of overhead gas.

The results from these moving measurements are calculations of emission rates and plume maps. The emission rates utilize the remotely sensed gas burdens and locally measured wind data. The plume maps are derived from both the overhead gas and ground-level gas measurements. Sixteen maps are included in this report, documenting the most significant

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events for each measurement day.

CONCLUSIONS

The moving laboratory is a useful means of detecting major stationary source plumes and tracing their ground-level impact. This methodology can be applied as a surveillance tool to monitor the emissions of SO_2/NO_x outside the property lines of sources. The ground-level impact these sources have on downwind air quality can be directly measured.

The two days of Moss Landing measurements were made under high, gusty wind conditions; plume detection was limited to 18 kilometers downwind with only minimal plume touchdown. The four days of Haynes/Los Alamitos measurements produced more comprehensive results; plume transport and touchdown were detected as far as 45 kilometers from the twin sources.

The plumes were quantified for SO_2 (and NO_2) emission rates as close as 100 meters from the stacks and as far as 26 km downwind. Remote sensing measurements were made in heavy fog (Moss Landing) and under gusty wind conditions. Maximum plume touchdown (Haynes/Los Alamitos) typically was found 10-12 km from the plants, and evidence of plume impact at ground-level was seen 24 km downwind.

Section 2

FIELD MEASUREMENTS

ACTIVITIES

EMI fielded an Air Quality Moving Laboratory (AQML) for
the ARB Power Plant Study. A crew of two persons brought the
equipment to the field (Figure 1) and operated it during day-
light hours on designated measurement days. Meteorological
forecasts by MRI were used to select the most suitable days
for measurements; response was within 24 hours. Remote sensor
measurement hours, which are dependent on daylight for instru-
ment operation in the passive mode, were approximately 0900-
1600 PDT. However, data were collected as early as 0830
and as late as 1845 PDT.

A total of 127 activity hours were logged during the
course of this study. Figure 2 is a summary of the activities
for the twelve days in the field. The hours of moving measure-
ments (shown shaded) totaled 54; the time required to travel
to the study sites, set up and calibrate the equipment, and
do routine maintenance was 73 hours.

Six AQML measurement days were designated by the ARB:
10 and 11 September, and 11, 16, 17 and 30 October 1974.
Supplementary moving measurements were made on 9 September
to check out the moving laboratory and on 31 October to
obtain additional measurements of the Haynes/Los Alamitos

Figure 1. Air Quality Moving Laboratory stopped for
calibration beneath fog shrouded Moss Landing stacks.

Figure 2.

ACTIVITY SUMMARY

DATE	TIME (PDT)

Chart showing activity bars across TIME (PDT) axis marked 0, 6, 12, 18, 24 for dates:
9 SEP, 10 SEP, 11 SEP, 10 OCT, 11 OCT, 15 OCT, 16 OCT, 17 OCT, 18 OCT, 29 OCT, 30 OCT, 31 OCT
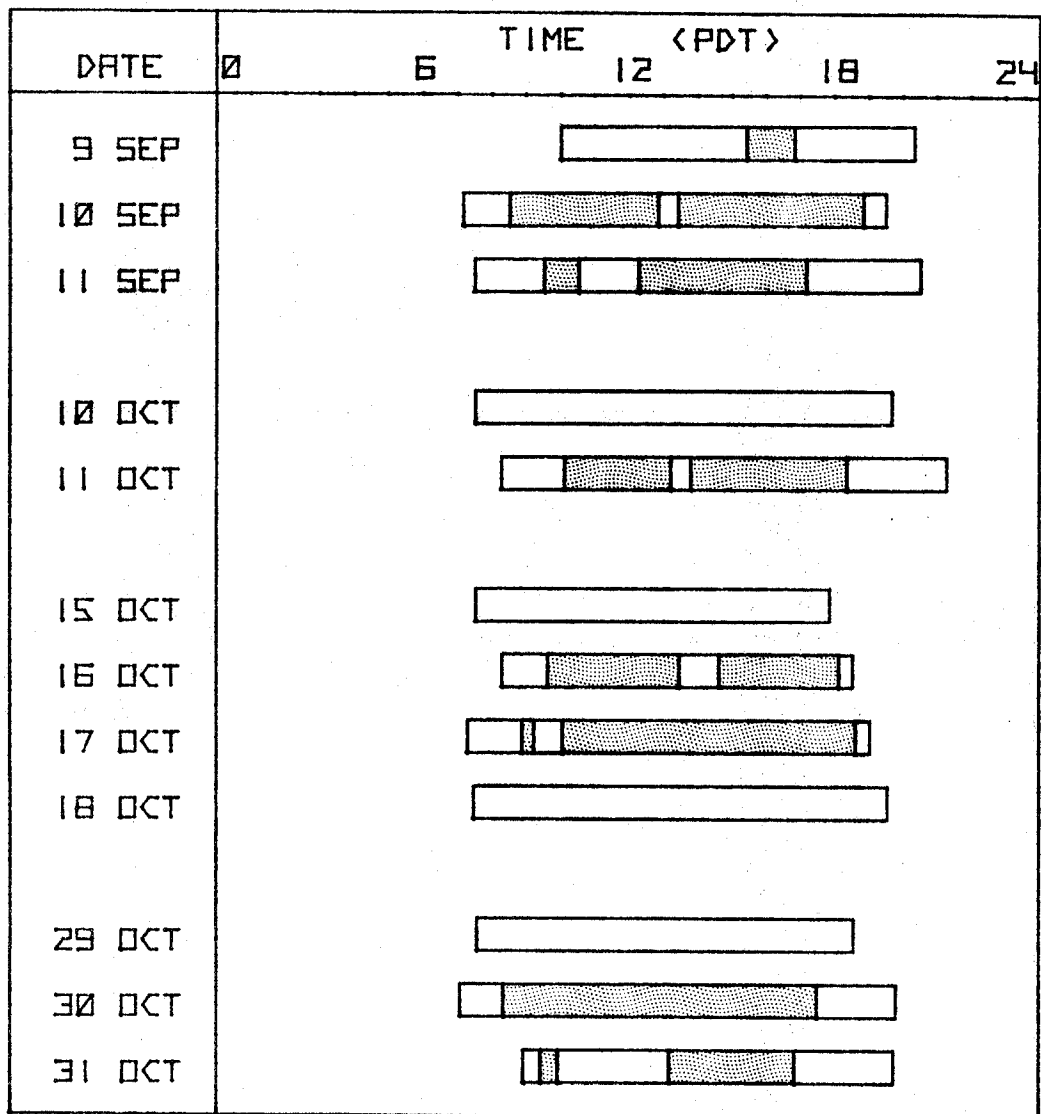
Legend:
� MOVING MEASUREMENTS
☐ TRAVEL/SETUP/MAINTENANCE

2-3

power plants and to survey other Long Beach area stationary sources. A total of 2566 km (1595 mi.) were travelled in the moving laboratory; on the typical measurement day 360 km (224 mi.) were covered.

A summary of activities for each data day follows:

MONTEREY

9 Sep 75:
The AQML was driven from EMI's Mt. View office to Monterey County. Initial traversing was done around the Moss Landing Power Plant; no significant data were recorded because the boilers were burning natural gas.

10 Sep 75:
Morning fog and an offshore breeze made regional measurements impossible. The emissions from Units 6 and 7 were monitored 17 times on CAL 1 (100 meters downwind) until 1300 PDT. The wind then rotated to a gusty onshore flow. A total of 14 plume cross-sections were made as far as 18 km from the plant.

11 Sep 75:
Fog and seaward winds again delayed regional measurements. Twenty short range plume measurements were made at 100 and 400 meters, the latter on the Moss Landing road west of CAL 1. Regional plume tracing was carried out from 1215 to 1700 PDT; 11 separate plume crossings were made.

LOS ANGELES

11 Oct 75:
The first plume measurements in Los Angeles began with light variable winds from the northwest. A wind shift occurred about 1230 PDT; with these more stable winds, extended surveying was done throughout the afternoon as far as 35 km from the Haynes/ Los Alamitos plants. SO_2 Burdens were measured until 1700 PDT; NO_2 COSPEC data were collected to 1820 PDT.

16 Oct 75:   There was a strong early morning inversion and low winds; plume measurements were made while the wind increased and rotated from north to northwest. By 1430 PDT the wind was from the west-southwest; the plumes were tracked eastward 45 km . The AQML returned to the plants and continued to measure plume touchdown.

17 Oct 75:   Morning traversing documented the diffuse plumes under light winds; plume definition under stronger southwest winds occurred by 1130 PDT. A three hour Z-traverse was started which extended 45 km downwind. The return survey confirmed plume location and impact at ground level. A western loop measured Dominguez Hills sources and an axial traverse north on I-605, along the plume centerline ended the day.

30 Oct 75:   Initial traverses were made between and around the two plants with variable southerly winds. The survey was extended 15 km to the north. Returning to the plants a survey was made between the power stations and a half hour was spent traversing inside the Los Alamitos facility. At 1330 PST a regional traverse was started; it continued to 1600 PST and ranged 45 km downwind.

EQUIPMENT

Environmental Measurements, Inc. provided an Air Quality Moving Laboratory (AQML) equipped to measure overhead SO_2/NO_2 and ground-level SO_2/NO_x. The AQML was equipped with a Correlation Spectrometer (COSPEC) remote sensor, a flame photometric total sulfur monitor and a chemiluminescent NO/NO_x analyzer (Figure 3). A teflon sampling manifold gathered air into the van by means of a squirrel cage fan; short teflon inlet tubes, in turn, sampled this air stream for analysis by the point monitors. The analog signals were recorded on a Rikadenki strip chart recorder. A rear-mounted propane-powered generator supplied electrical power for all instrumentation.

The Barringer Research COSPEC III viewed the sky through a side window in the van, using a right angle mirror to reflect overhead light. The natural radiation of the solar electromagnetic spectrum is influenced by the absorption spectrum of the target gases, sulfur dioxide and nitrogen dioxide. The Correlation Spectrometer, an electro-optical instrument, detects portions of the molecular absorption bands specific for these molecules. The optical unit includes a Cassegrain telescope, an Ebert-Fastie quarter-meter dispersive element, a correlation disc assembly, and a photomultiplier to detect light energy levels. The electronics
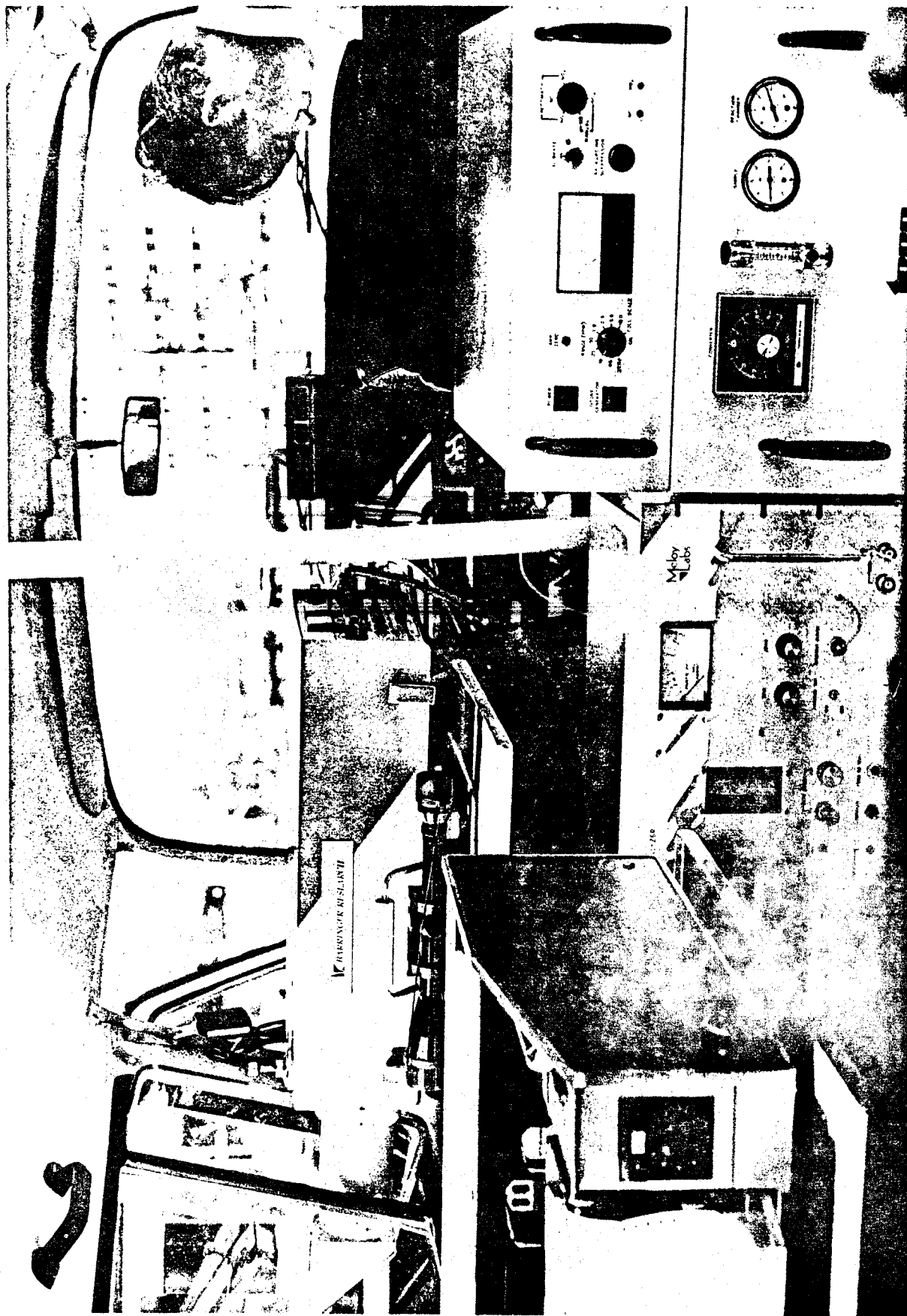
Figure 3. Interior of Air Quality Moving Laboratory: COSPEC (above) and recorder, flame photometric and chemiluminescent monitors (left to right).

of the COSPEC contain signal processing circuits to provide
an analog output suitable for strip chart recorders. Two
COSPEC III's were used in the study; Serial No. 6061 was used
in Monterey and Serial No. 5932 in Los Angeles.

Table I
COSPEC CALIBRATION CELL CONCENTRATIONS

Serial No.	SO_2 (ppmM)		NO_2 (ppmM)	
	Low	High	Low	High
5932	75	180	38	115
6061	87	418	15	138

Calibration of the COSPECs was carried out approximately
every 30-60 minutes in the field. It was performed by actuat-
ing a pair of knobs to place two gas-filled quartz cells
(labeled "low" and "high") into the instruments' internal
light path. These cells contain fixed amounts of SO_2 and NO_2
in a dry nitrogen atmosphere. They provide span offsets ac-
cording to the values in Table 1. When possible, this was
done in regions of background SO_2/NO_2, away from plumes, just
prior to or following a traverse. Notations of the time and
the cells used during the calibration and the recorder sensi-
tivities were made on the chart record. The voltage for the

automatic gain control (AGC) circuit was also noted on the chart record to provide an indication of the changing light intensity during the day.

There were 78 COSPEC calibrations in six days; the average sensitivity for each gas was calculated for each instrument, each day. The typical standard deviation as a percent of the mean of these averages is 5% for SO_2 and 2% for NO_2.

The Bendix Corporation Model 8300 Total Sulfur Monitor (Serial No. 30301) was calibrated with the Bendix permeation system containing permeation tube No. NBS 1627-18-13. The instrument was calibrated before and after the September measurements and within 10% of the anticipated permeation rate.

The Meloy Model SA-185 Total Sulfur Monitor (Serial No. 2C085) was used for the October measurements. It was calibrated on the same Bendix permeation system. The calibrations before and after the field work were both within 5% of the theoretical value.

The Thermo Electron Oxides of Nitrogen Analyzer (Serial No. AAM-0904-26) was calibrated using a MG Scientific gas cylinder as a reference. The NO_x data in this report are accurate within ± 10%.

A supplementary data collection technique was provided by EMI for the Northern California measurements. An EMI

Pulse Pump with sampling bags was loaned to the CIT field

crew for collection of time-averaged air samples for later

analysis of sulfur hexaflouride (SF_6). Also, moving measure-

ments of SF_6 were made at Moss Landing with a technician

riding in the AQML making periodic grab samples with syringes

at points coincident with the centerline of the remote-sensor-

located plume.

Another supplementary field activity occurred in Los

Angeles when a time-lapse motion picture camera was located

on the roof of a building approximately one kilometer east

of the power plants to record plume and cloud activity during

the day. A film for 30 October 1974 is available as part

of the data record for this study.

METHODOLOGY

The methods used to obtain moving measurements of
power plant plumes are unique to EMI. The moving laboratory
data must be related to the geography of the study site.

Geographic Labeling. Prior to the actual field work
a set of U.S. Geological Survey Topographic Maps (7.5 minute)
was annotated with numerical identifications of key road
intersections. By labeling the most likely routes for
traversing in advance, a systematic identification system
was used for the entire study. During a traverse, the
identification numbers from these maps were recorded on the
chart record to locate where the value for Total Burdens and
ground-level concentrations of the target gases were recorded.

Traversing. On arrival at the power plant at the start
of a data-day, preliminary traverses were made in the AQML
to confirm the overhead location of the plume. Normally
a set of plume crossings is made at one radius from the
power plant and the AQML is moved to a different radius --
closer or farther from the plant -- for another set of mea-
surements.

At Moss Landing the mornings were limited to plume
crossings on two roads 100 meters and 400 meters from the
stacks because of offshore winds. Longer distance measure-
ments were made only after the wind rotated about mid-day.

At the Haynes/Los Alamitos plants similar restrictions were experienced. The steady on-shore wind did not develop until late morning, requiring near-plant measurements (Figure 4) until traversing could be done.

For regional plume tracking the moving laboratory was traversed back and forth at increasing radii from the source. In this way data were gathered in a "Z" pattern to map the dispersal of emissions from the power plants. As many as seven different traversing radii were used for one set of conditions, requiring two or three hours to complete.

Traversing speed varied with the distance from the source. Close to the power plant speed was kept low (below 30 km/hr) to allow the instruments to respond fully and to provide clear definition of narrow plumes. As the AQML moved further downwind from the plant it moved faster through the plume. The speed of the vehicle increased to a maximum of 90 km/hr at the farthest radius. This increase in speed permitted the field crew to travel under the plume in the shortest possible time. Because the plume is broader at the greater distances, changes in overhead burdens and ground-level concentrations were less abrupt, and the instruments responded to them easily.

Frequent observations of local wind conditions were made to guide the surveys. The remote sensor usually
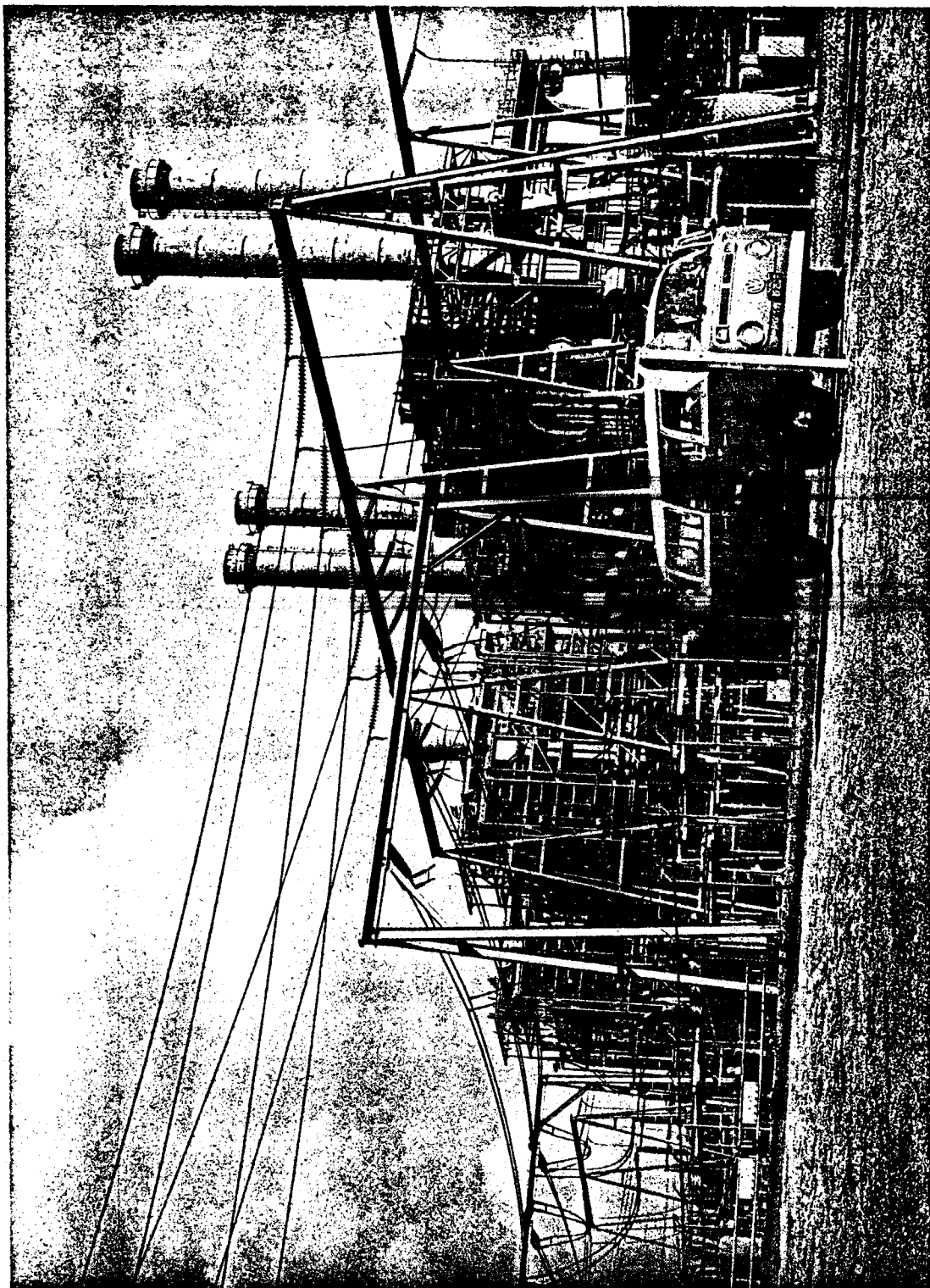
Figure 4. Traversing between the Los Alamitos and Haynes (shown above)
Power Plants provided initial data on relative source strength and plume vector.

provided enough data to determine the wind vector. Verification of wind directions with a helium-filled pilot balloon was useful when surface winds differed from winds aloft. By observing the pibal (Figure 5) with the naked eye a semi-quantitative reading was obtained of wind conditions at elevations likely to influence the target plume.

Field Crew. A two person field crew operated the EMI moving laboratory. One person was the driver while the other was the data-logger who entered onto the strip chart record the locations, times and points of instrument zero and span calibration.

Decisions were made in the field based on the real-time data: whether to repeat the plume-tracking measurement at the present radius or to move to a second radius of measurement; whether to turn right or left to recross the dispersing plume at a different radius.

A transceiver was used intermittently to communicate with the MRI aircraft. Radio contact was achieved while the AQML was moving and when stopped for calibration. This real-time communication between the AQML and the instrumented aircraft was intended to insure close coordination between the two mobile units. On several occassions the information exchange did confirm plume locations. But because the moving and flying laboratories had different
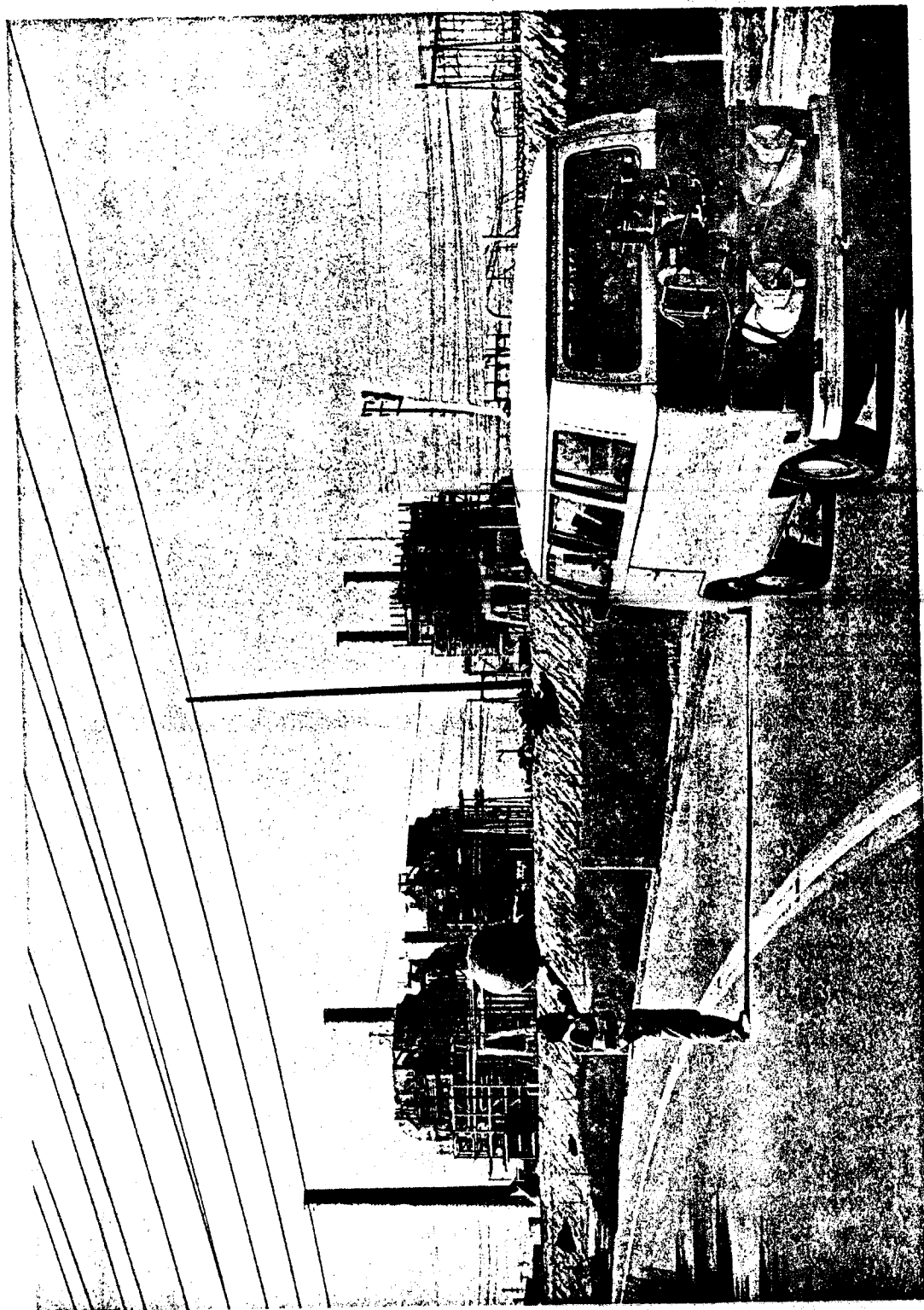
Figure 5. Pibal release near Los Alamitos Power Plant gives winds aloft information prior to a regional traverse.

sampling protocals only limited simultaneous plume measure-
ments were made. However, the method should be refined for
future plume studies.

Section 3

DATA PROCESSING

The data collected at the field sites were taken to the EMI office in San Francisco for processing. The chart records were first annotated to define Events, separating individual measurements into an orderly list. Each Event was assigned beginning and ending times for correlation with other contractor's results.

DIGITIZATION

The raw moving laboratory data were in the form of strip chart records, the analog traces for SO_2 and NO_2 Total Burdens and SO_2 and NO/NO_x ground-level concentrations. Reference baselines were drawn for the SO_2 and NO_2 Burden records. The background was defined as the instrument output on either side of well defined plume anomalies (See Figure 6 for example of background reference line). These records also included hand-written annotations of time and positions made by the data-logger, as well as instrument calibrations and weather conditions.

Using a combination of machine and hand digitization methods each analog trace was sampled at inflection points and at geographic reference points. Major assumptions of this procedure are a constant velocity of the vehicle between indicated landmarks, and straight line interpolation between geographic points and inflection points. Therefore, assuming

straight line variations between each of the digitized points, they may be joined by straight lines to recreate the original record. Figure 6 is a sample data trace showing the analog signals marked for digitization.

These digitized values were entered on punched cards; a set of cards represents one event (e.g. a single plume cross section). These data were then stored in the computer memory for later use.

All of the geographic location points were digitized from a suitable base map into X and Y coordinates. The Universal Transverse Mercator (UTM) system (in kilometers) provided a convenient reference grid. Each of these coordinates was stored in the computer memory and assigned an ID number. These ID numbers were subsequently used to refer to the geographic points for map making. Route Index Maps, Figures 7 and 8 display all the routes used during the survey (major ones are labeled) and the geographic references (coastlines, sources) used on the Flux and Ground Maps.

The two sets of stored data -- time/pollutant and geographic -- were merged by the computer into listings of seven parameters in engineering units:

Figure 6

SAMPLE CHART RECORD
COSPEC III Output

10 September 1974, 1052-1109 PDT, Events 5-8
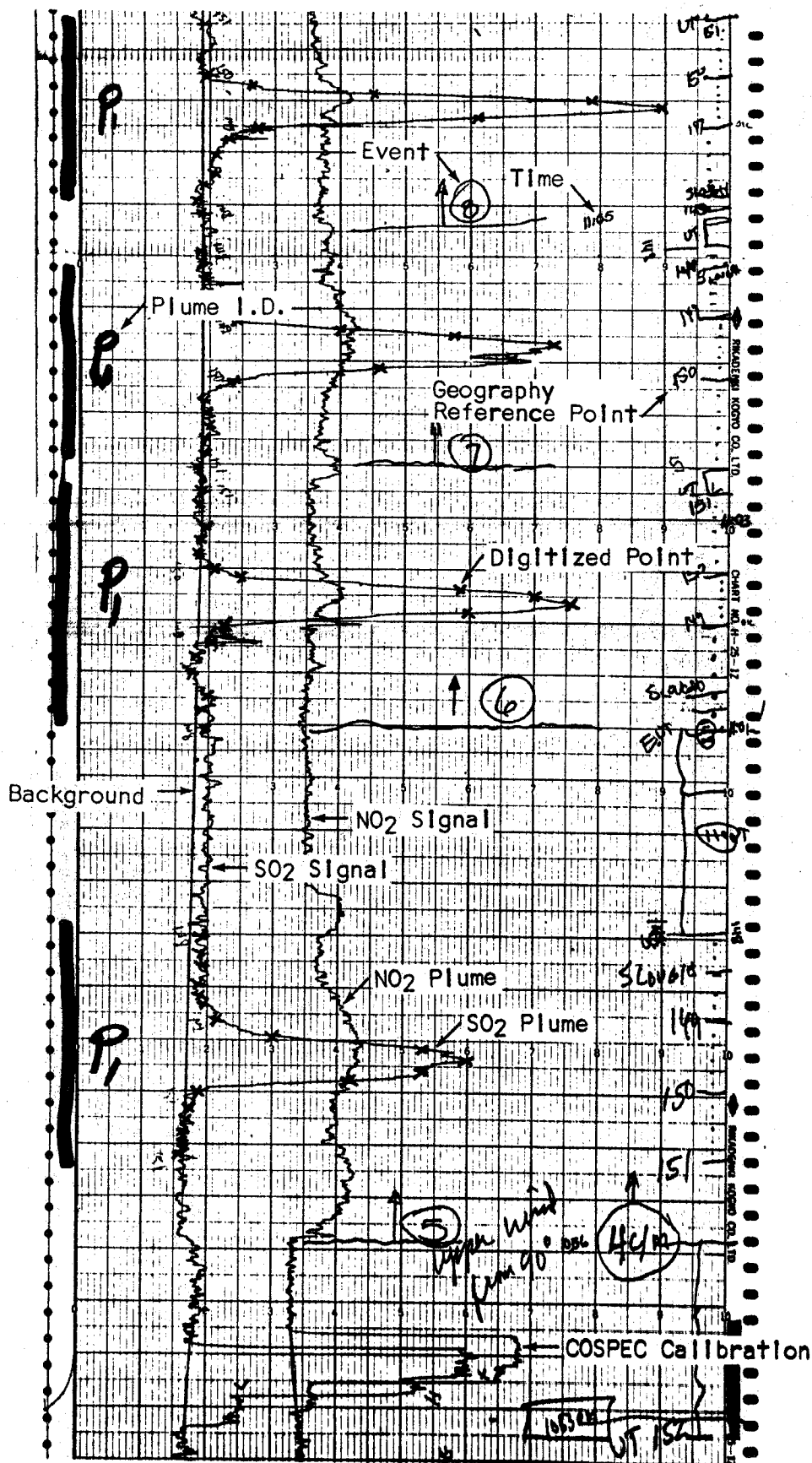
ROUTE INDEX MAP
ARB POWER PLANT STUDY
10-11 SEPTEMBER 1974
NORTH CENTRAL COAST AIR BASIN

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 7

Target Power Plant

Dolan

Cal-1

Cal-1

US-101

CAL-156

Espinosa

Cal-183

US-101

Main

N

1 km

1:100,000
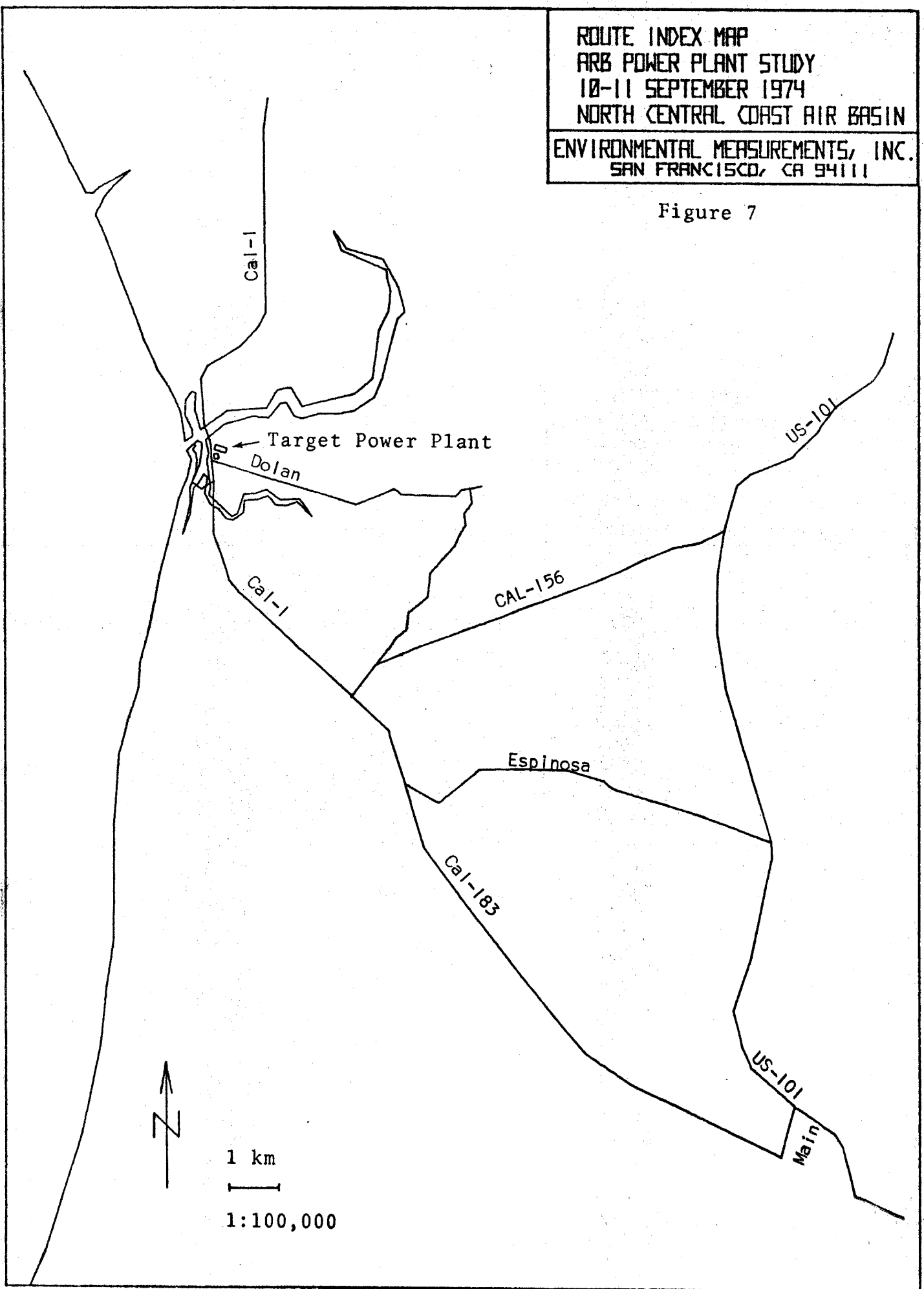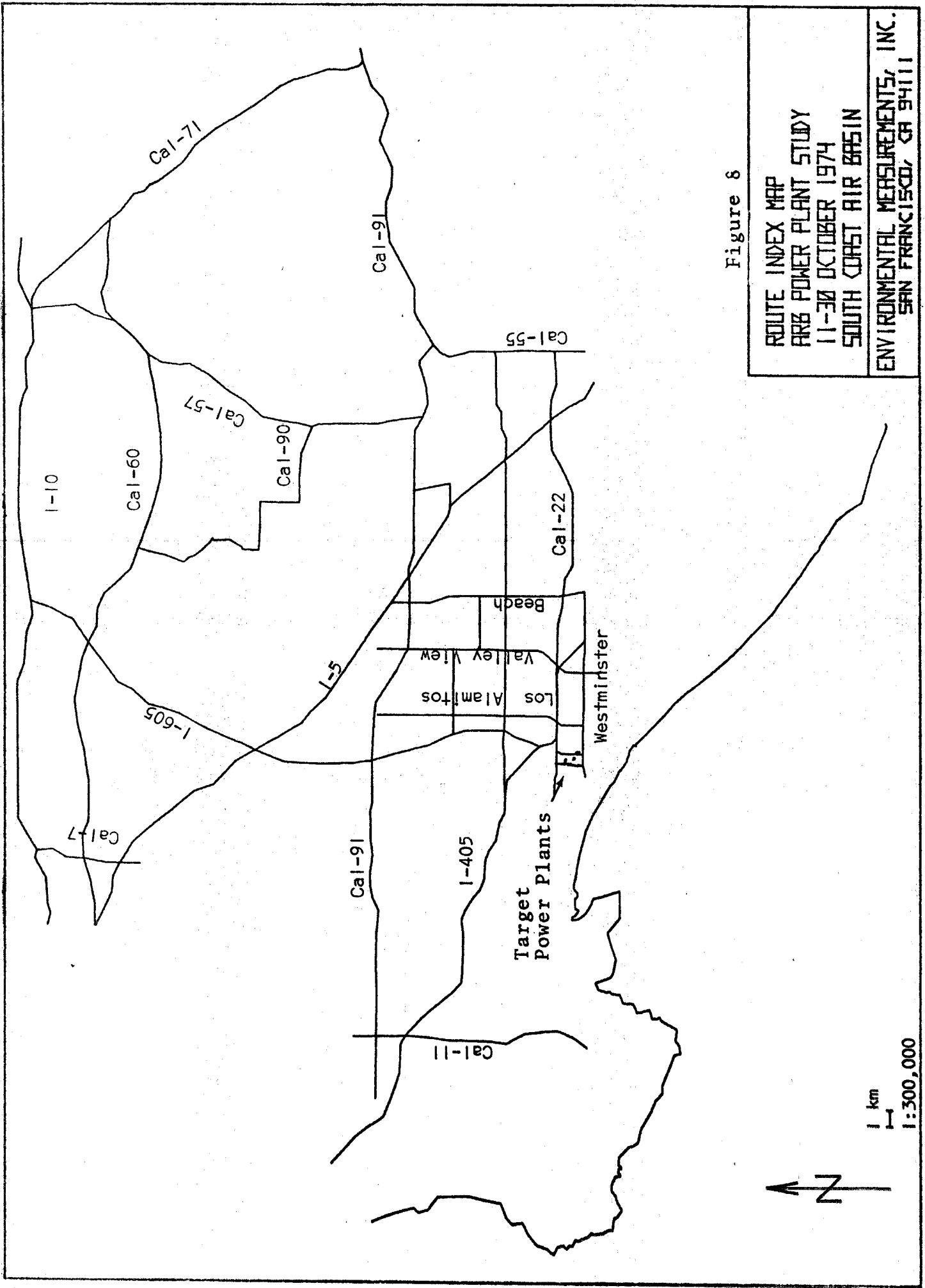
Figure 8

ROUTE INDEX MAP
ARB POWER PLANT STUDY
11-30 OCTOBER 1974
SOUTH COAST AIR BASIN

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Cal-71

Cal-91

Cal-55

Cal-57

Cal-60

I-10

Cal-90

Cal-7

I-605

I-5

Cal-22

Beach

Valley View

Los Alamitos

Westminster

Cal-91

I-405

Target
Power Plants

Cal-11

N

1 km
1:300,000

3 5

- Time (PDT)
- X Coordinate (km)
- Y Coordinate (km)
- SO_2 TB (ppmM)
- NO_2 TB (ppmM)
- SO_2 GL (ppb)
- NO_x GL (ppb)

An example of a data listing for this study is shown in Figure 9. Listings of all data processed for this report -- and for still undigitized data -- can be provided on request.

WIND DATA

An important parameter in the calculation of pollutant flux is the wind speed at the elevation of the plume. EMI did not collect wind data for this study but relied on measurements by two MRI pibal teams. Copies of the pibal data were provided by MRI along with streamline analyses based on surface wind speed data.

In general, the pibals were launched from two sites on the hour starting as early as 0900 and ending as late as 1900 PDT. Because of differences in both time and location between the pibals and the AQML traverse routes the wind data were studied by EMI to select appropriate directions and speeds for computer mapping.

First it was necessary to determine the mixing height so that proper winds could be chosen for flux calculations. Each hourly pibal was averaged for both direction and speed.

Figure 9
SAMPLE AQML DATA LISTING
17 October 1974, Event II, String IV

TIME PST	X KM	Y KM	SO2-TB PPM-M	NO2-TB PPM-M	SO2-GL PPB	NOx-GL PPB
1210.	396.90	3740.71	16.0	9.2	87.	10.
1210.	397.26	3740.70	16.0	9.2	79.	10.
1210.	397.62	3740.70	8.0	4.6	76.	9.
1210.	397.97	3740.70	8.0	9.2	76.	8.
1211.	398.33	3740.69	16.0	4.6	69.	8.
1211.	398.48	3740.72	8.0	13.8	60.	8.
1211.	398.63	3740.74	.0	9.2	55.	8.
1211.	398.79	3740.76	.0	4.6	58.	8.
1211.	398.94	3740.79	.0	4.6	58.	8.
1211.	399.02	3740.79	.0	9.2	58.	8.
1212.	399.10	3740.79	16.0	4.6	58.	8.
1212.	399.18	3740.79	.0	4.6	55.	8.
1212.	399.26	3740.79	.0	4.6	52.	8.
1212.	399.44	3740.76	.0	4.6	50.	8.
1212.	399.61	3740.73	8.0	.0	48.	9.
1212.	399.79	3740.71	.0	6.9	44.	9.
1213.	399.96	3740.68	8.0	11.5	44.	11.
1213.	400.18	3740.68	80.0	18.4	42.	13.
1213.	400.41	3740.67	132.0	36.8	48.	14.
1213.	400.63	3740.67	168.0	50.6	66.	17.
1213.	400.85	3740.67	168.0	50.6	63.	17.
1213.	401.06	3740.66	200.0	52.9	63.	16.
1214.	401.26	3740.65	184.0	48.3	63.	14.
1214.	401.46	3740.65	188.0	59.8	69.	13.
1214.	401.66	3740.64	160.0	55.2	63.	12.
1214.	401.86	3740.64	168.0	52.9	58.	10.
1214.	402.07	3740.64	192.0	55.2	48.	9.
1214.	402.27	3740.64	224.0	50.6	42.	9.
1215.	402.47	3740.64	228.0	50.6	38.	9.
1215.	402.67	3740.64	152.0	55.2	32.	8.
1215.	402.88	3740.64	140.0	39.1	32.	8.
1215.	403.08	3740.64	112.0	36.8	32.	6.
1215.	403.28	3740.64	92.0	34.5	30.	6.
1215.	403.68	3740.63	56.0	32.2	29.	5.
1216.	404.07	3740.62	40.0	16.1	28.	5.
1216.	404.47	3740.61	16.0	13.8	26.	5.
1216.	404.87	3740.61	8.0	16.1	28.	5.

Next, each Flux Map route and the Burden data were reviewed to determine which of the pibals were appropriate (often 20 km away from the plume measurements) and whether more than one wind direction or speed was necessary (because of wind changes during the traverse). To account for the variations in the times and locations of the pibal measurements interpolation was necessary to obtain representative wind speeds and directions. The interpolation was done on an individual basis depending on the time and space differences and on the trends in the wind data.

A final adjustment in wind directions was made by checking the EMI Burden data to determine the compass angle of the line from the source(s) to the measured plume peak(s). This figure usually was within five degrees of the averaged pibal direction. On occasions there were differences caused by topographic influences on wind flow. In such cases, the direction determined from the Burden data was used for map plotting.

MASS FLUX

Calculations. The computation of mass flux -- emission rate of a source -- derived from the COSPEC Total Burdens (SO_2 and NO_2), the geography, and the wind speed according to the following formula:

$$\begin{array}{ccccc}
\text{MASS} & \text{TOTAL} & \text{TRAVERSE} & \text{WIND} & \text{WIND/ROAD} \\
\text{FLUX} = & \text{BURDEN} \times & \text{LENGTH} \times & \text{SPEED} \times & \text{ANGLE}
\end{array}$$

$$(\frac{gms}{sec}) = (\frac{gms}{meter^2}) \quad (meters) \quad (\frac{meters}{sec}) \quad (sin \alpha)$$

[Emis-   [Cospec   [Map
sion]   Reading]   Distance]   [Pibal or Anemometer]

All of the parameters were measured in the field; the COSPEC provided the Total Burden, and the annotated chart record provided the geographic data for determining the Traverse Length and the Wind/Road angle; the wind speed (assumed constant) was from the MRI pibal results.

The computer-stored data were operated on by a proprietary computer program to calculate SO_2 and NO_2 Flux over each segment of road travelled by the AQML. Figure 10 is a sample printout of a Mass Flux calculation.

Error Estimate. The accuracy of the flux computations can be estimated from the errors of individual parameters. There are six identifiable sources for error in the data collection and processing procedures: spectrometer precision, spectrometer calibration, spectrometer record interpretation, wind speed, wind direction and burden location. Each of these errors is a random quantity which takes on different

Figure 10

Sample Flux Calculation

```
30TH OF OCTOBER SF REGIONAL MAP (B)
WIND =  4.0 M/S FROM231, DEGREES
SO2 ANALYSIS
ENHANCED STRING NUMBER  4
```

BRING*	R	S	AVZ	SIN(R)	FLOW	SUM
.2	-230.8	322.8	24.	.775	5.5	5.5
.2	-230.8	322.8	24.	.775	5.5	11.0
.2	-230.8	322.8	24.	.775	5.5	16.5
.2	-230.8	322.8	24.	.775	5.5	22.0
353.2	122.2	295.5	24.	.846	5.6	27.7
346.6	115.6	277.3	26.	.902	5.9	33.6
346.6	115.6	277.3	27.	.902	6.3	39.9
346.6	115.6	277.3	29.	.902	6.7	46.5
346.6	115.6	277.3	31.	.902	7.0	53.5
16.3	-214.7	439.0	32.	.570	7.3	60.8

```
        TOTAL MASS FLOW =   60.8 METRIC TONS PER DAY.
TOTAL TRAVERSE LENGTH =   3.13 KILOMETERS.
```

*See Glossary, page G-3, for explanation of column headings.

(and unpredictable) values from traverse to traverse. The
first three error sources are related to the operation of
the spectrometer; the next two pertain to wind data used in
the flux calculations; the last occurs in transferring
original data records onto digitized maps.

COSPEC III non-linearity (above 500 ppmM) is treated
as part of the spectrometer calibration error. The calcu-
lated instrument sensitivity is used to convert the digitized
spectrometer outputs from millivolts to parts-per-million-
meters. Corrections for occasional readings greater than
500 ppmM are made prior to the calculation of flux.

An estimate of the expected error in the Flux results
can be made by assigning individual values to each of the
six component errors (V_i) and making a root-mean-square
calculation. The equation is:

$$\text{RMS Error} = \sqrt{V_1^2 + V_2^2 + \dots + V_n^2},$$ where V_i
is the RMS error of one of the contribu-
ting sources of error.

The values of each error for the SO_2 data gathered in
this study are:

Spectrometer precision	± 7%	(average noise as a percent of signal within one kilometer of source)
Spectrometer calibration	± 5%	(actual daily variation in field calibrations)

Spectrometer interpretation   ± 5%   (typical error in
                                          determining reference
                                          baselines on chart records)

Wind speed   ±15%   (expected variation in
                                          extrapolating fixed-site
                                          wind data to plume location)

Wind direction   ± 3%   (average error in determin-
                                          ing wind direction (a)
                                          when converted to sine a)

Burden location   ± 8%   (combined field notation
                                          and data handling errors
                                          of geographic locations)

The computed RMS Error for a SO_2 Mass Flux calculation is:

$$RMS\ Error = \sqrt{(7)^2+(5)^2+(5)^2+(15)^2+(3)^2+(8)^2}$$

$$= \pm 20\%$$

For NO_2 the RMS Error is slightly less (±19%) because of
lower spectrometer precision (±4%) and calibration (±2%)
values.

This RMS Error incorporates the principal sources of
error in making remote sensor measurements and converting
the results to emission rates. Its actual value for each
SO_2 Mass Flux calculation may be less than ±20%. For
example, if the actual wind speed error is ±5% (rather than
±15%) the RMS Error is reduced to ±14%.

Conversely, for plume crossings 10 km from the source
the spectrometer precision can increase from ±7% to ±20%;
the resulting RMS Error is ±26%. To accurately determine
a flux value, therefore, a number of separate measurements

(usually six but at least three) are made and the results averaged; this averaging procedure cancels out random errors and reduces the error by a factor of $1/\sqrt{n}$. Therefore, while the RMS Error of a *single* flux calculation would be ±20%, it would be ±8.2% (±20%/$\sqrt{6}$) for the average of a *set of six* calculations.

FLUX MAPS

The computer program that performs flux calculations also produces computer plotted maps. These maps display flux lines on the roads travelled by the AQML. The lines extend from the roadway in the direction of wind flow; the length of the lines is proportional to the Flux, calibrated in metric tons per day (MT/D) rate of emissions. A plume anomaly recorded on the original data in parts per million-meters (ppmM) thus appears on the map (modified by the wind speed and direction) as flux lines showing the "shape" of the overhead gas. By summing the lines for a given plume the total emission rate can be determined directly from the map.

The 16 maps in this report contain the coastlines as geographical references and locations of the target power plants. The geographic scale and the SO_2/NO_2 flux scales

are shown on each Flux Map; the selected wind speed labels the wind arrow.

In addition to Flux Maps there are four Ground-Level Maps. The ground-level data are plotted as ladder rungs, lines normal to the traverse route; they are calibrated in parts per billion (ppb) SO_2 or NO_x. (The sulfur monitors detected Total Sulfur; however, for this study the target gas was SO_2 and the reasonable assumption has been made that the ground-level gas measured was largely, if not all SO_2.) The Ground-Level Maps are printed on vellum to facilitate simultaneous viewing of the results with the Flux Maps which appears on the following pages.

Section 4

RESULTS

The results of the power plant study are presented in map form. A total of 16 maps have been plotted for six data-days. A majority of the maps are on a regional scale; some maps have been plotted for data gathered within a kilometer of the target power plants. The scales of the data lines -- for both the mass flux and ground-level results -- are the same for all maps to facilitate comparison from one map to the other. SO_2 and NO_2 flux maps are plotted at a scale of 10 metric tons for each centimeter; the SO_2 and NO_x ground-level maps are at a scale of 50 ppb for each centimenter. The single NO_x ground-level map is scaled at 250 ppb per centimeter.

The ground-level maps are printed on translucent material. They are bound into the report as overlays to the corresponding Mass flux maps. Viewed together, these map pairs afford a graphic display of the overhead plume and ground level impact as observed in the field.

The maps are presented in chronological order by day. Each daily set of maps is preceded by a brief narrative description of the pertinent results. The maps are indexed in Table II.

Table II

Map Index

DATE	GAS	TYPE	SCOPE
10 Sep 74	SO_2	Flux	Near Plant
	SO_2	Flux	Near Plant
	SO_2	Flux	Regional
11 Sep 74	SO_2	Flux	Near Plant
	SO_2	Flux	Regional
11 Oct 74	SO_2	Flux	Regional
	NO_2	Flux	Regional
16 Oct 74	SO_2	Ground	Regional
	SO_2	Flux	Regional
17 Oct 74	SO_2	Ground	Regional
	SO_2	Flux	Regional
	NO_x	Ground	Regional
	NO_2	Flux	Regional
30 Oct 74	SO_2	Ground	Regional
	SO_2	Flux	Regional
	NO_2	Flux	Regional

A pair of near-plant maps and a regional plume survey map
form the set for the first day of the study.

Figure 11 is a plot of an average plume measured on Cal-1
100 meters west of the stacks. Taken from a series of seven
measurements over a 23 minute period the calculated mass
flux is 47.1 MT/D SO_2, at a wind speed of 1.8 M/S.

Figure 12 shows a much broader plume. This series of
measurements, seven later plume crossings in 69 minutes,
shows an average plume width three times that recorded during
the earlier set of measurements. The calculated mass flux
is 87.7 MT/D SO_2.

The plume crossings plotted in Figure 13 were gathered
over a period of 63 minutes in mid afternoon. These measure-
ments were made under extremely gusty wind conditions.
Because of observed fluctuations in plume geometry average
plumes are not plotted; rather, selected individual plumes
are shown to represent typical measurements made during this
time period. The SO_2 flux measured nearest the power plant is
58.0 MT/D.

SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
10 SEPTEMBER 1974
1103-1126 PDT   EVENTS 5 -11
ENVIRONMENTAL MEASUREMENTS, INC.
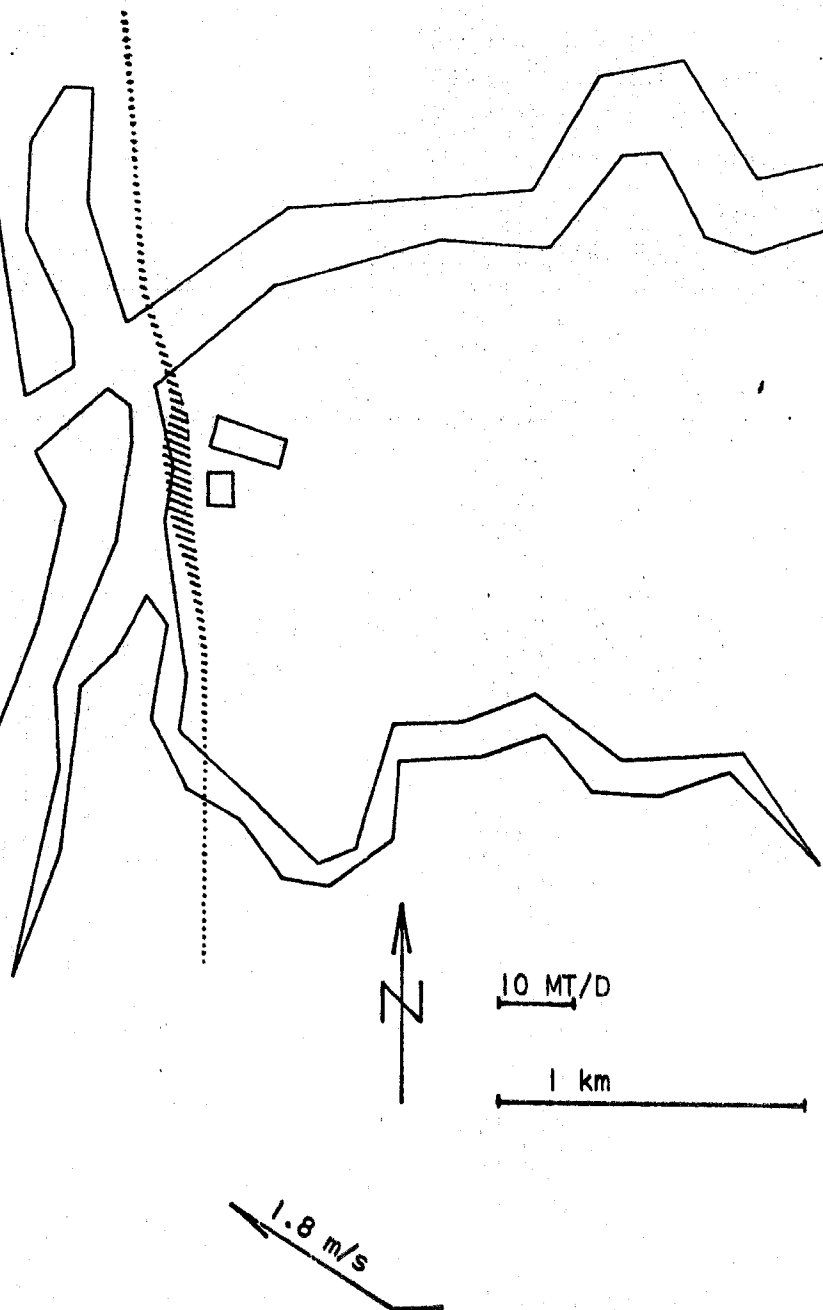SAN FRANCISCO, CA 94111

Figure 11

N

10 MT/D

1 km

1.8 m/s
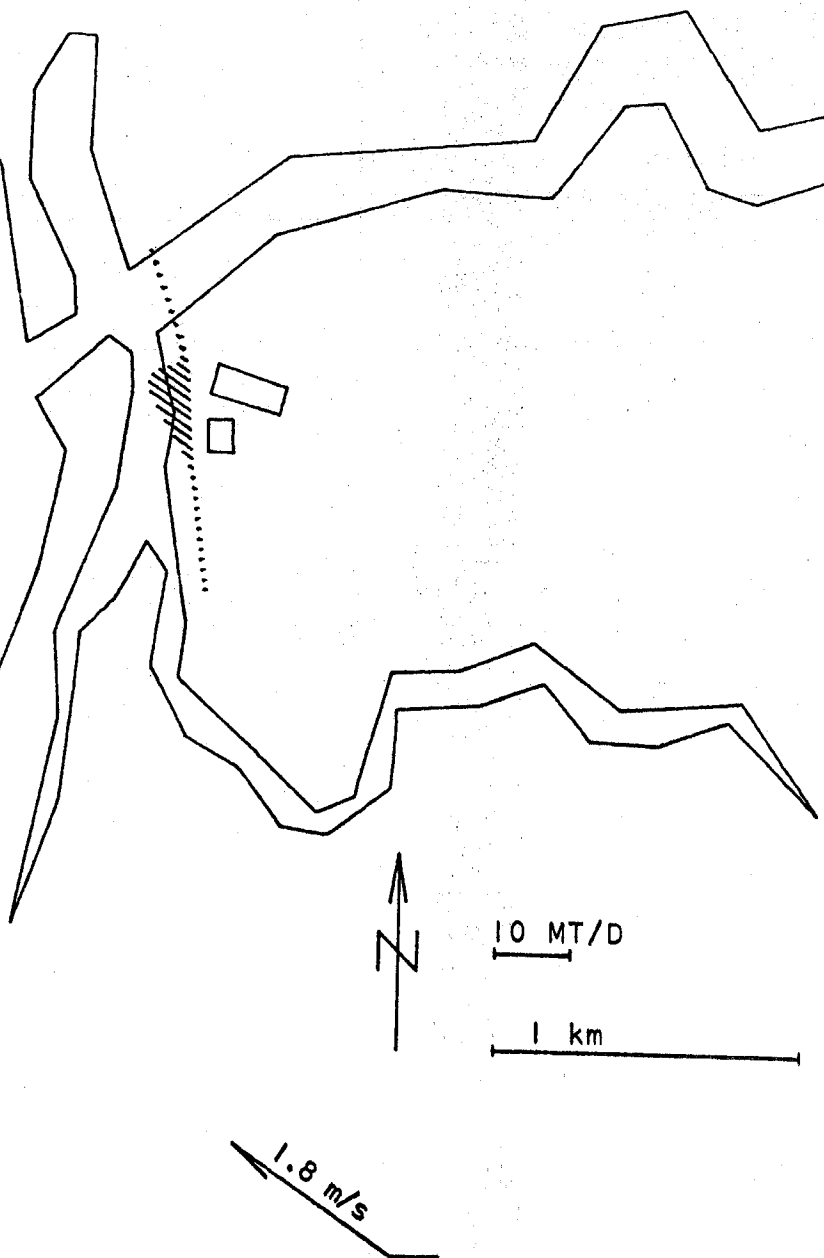
SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
10 SEPTEMBER 1974
1126-1235 PDT   EVENTS 12-18

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111
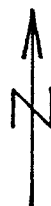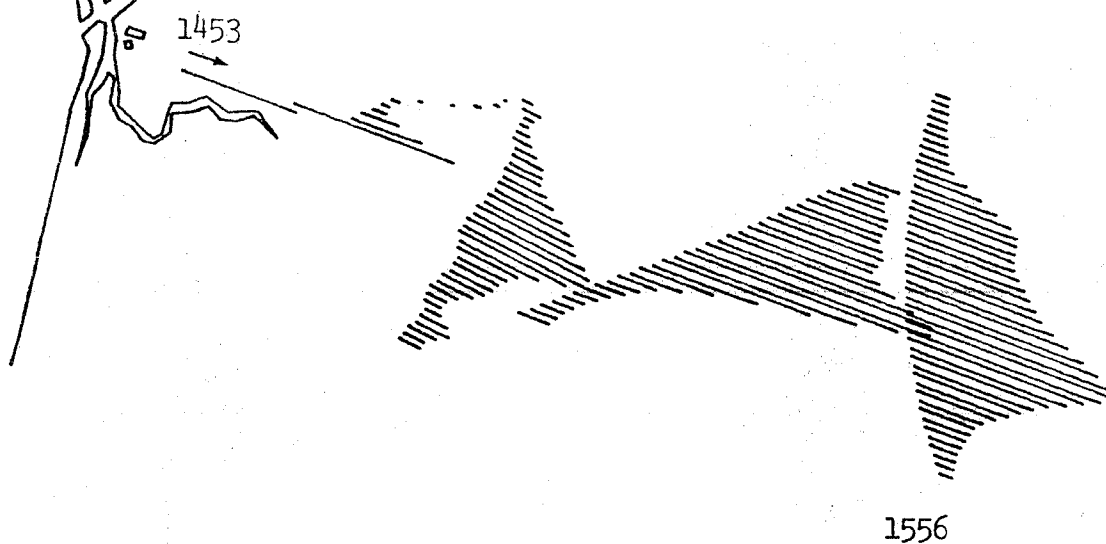
Figure 12

10 MT/D

1 km

1.8 m/s

SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
10 SEPTEMBER 1974
1453-1556 PDT   EVENTS 30-34

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 13

11 September 1974 - Moss Landing

The two-map set includes one near plant SO_2 flux map and one regional map.

Figure 14 presents two sets of measurements of the power plant plume made at 100 and 400 meters downwind. The plotted lines represent the average plume of ten traverses made over a period of 73 minutes during the early morning. Using a selected wind speed of 3.3 M/S the calculated mass flux is 85.8 MT/D SO_2 for the near plume crossing and 79.0 MT/D for the far one.

Figure 15 depicts the plume as it was crossed four times at radii ranging from one to sixteen kilometers. The three nearest plume plots have averages of 2 crossings each; the far distance crossing is a single traverse.

The wind was gusty during this afternoon survey; a speed of 6.0 M/S was selected from the pibal data. The mass flux values are estimated after background SO_2 was removed from the total calculated fluxes. The net values, for increasing downwind distance, are 44.2, 86.0, 47.2, and 62.2 MT/D SO_2; average: 59.9 MT/D.

SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
11 SEPTEMBER 1974
0919-1032 PDT   EVENTS 2 -12
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111
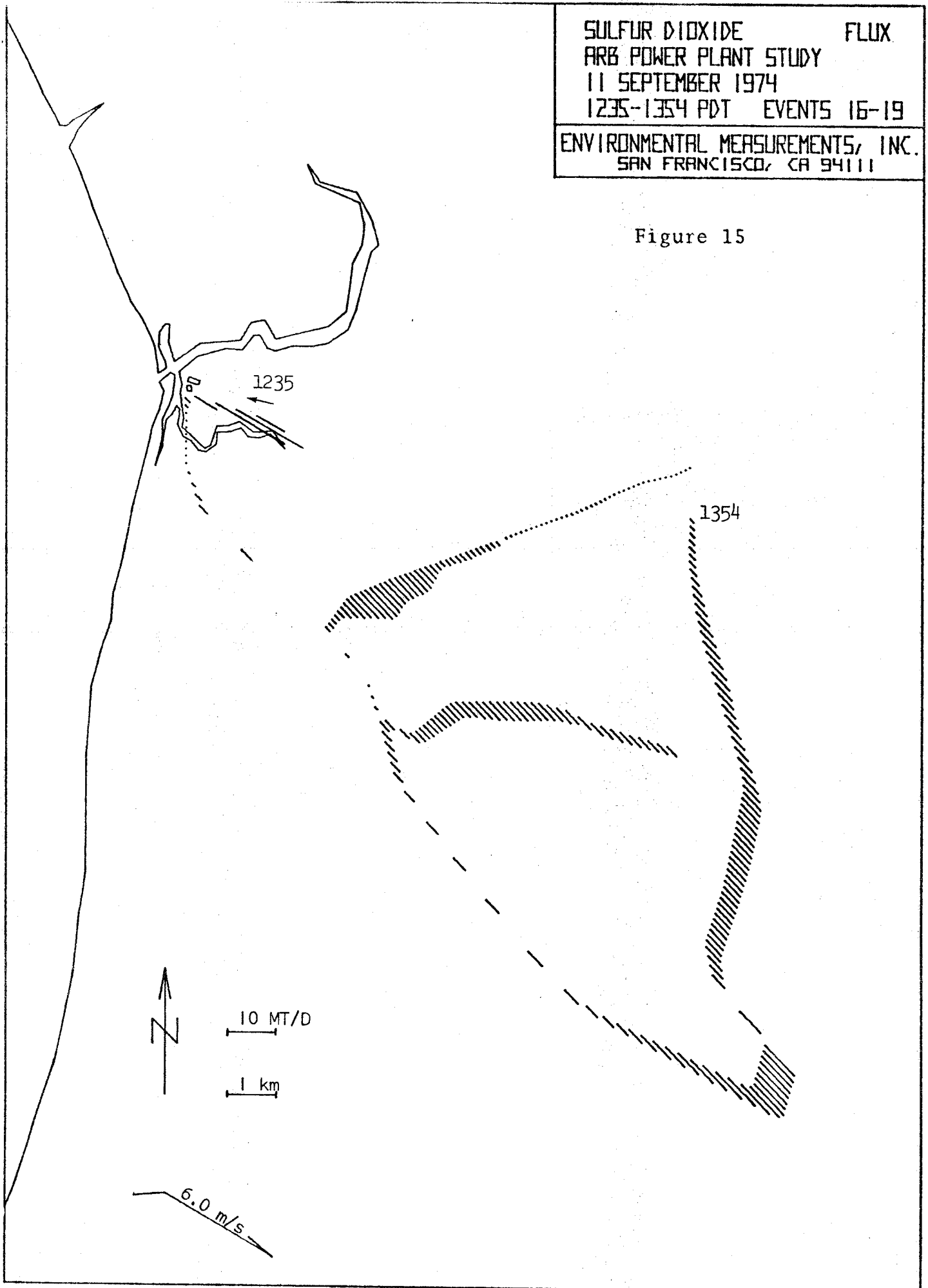
Figure 14

10 MT/D

1 km

3.3 m/s
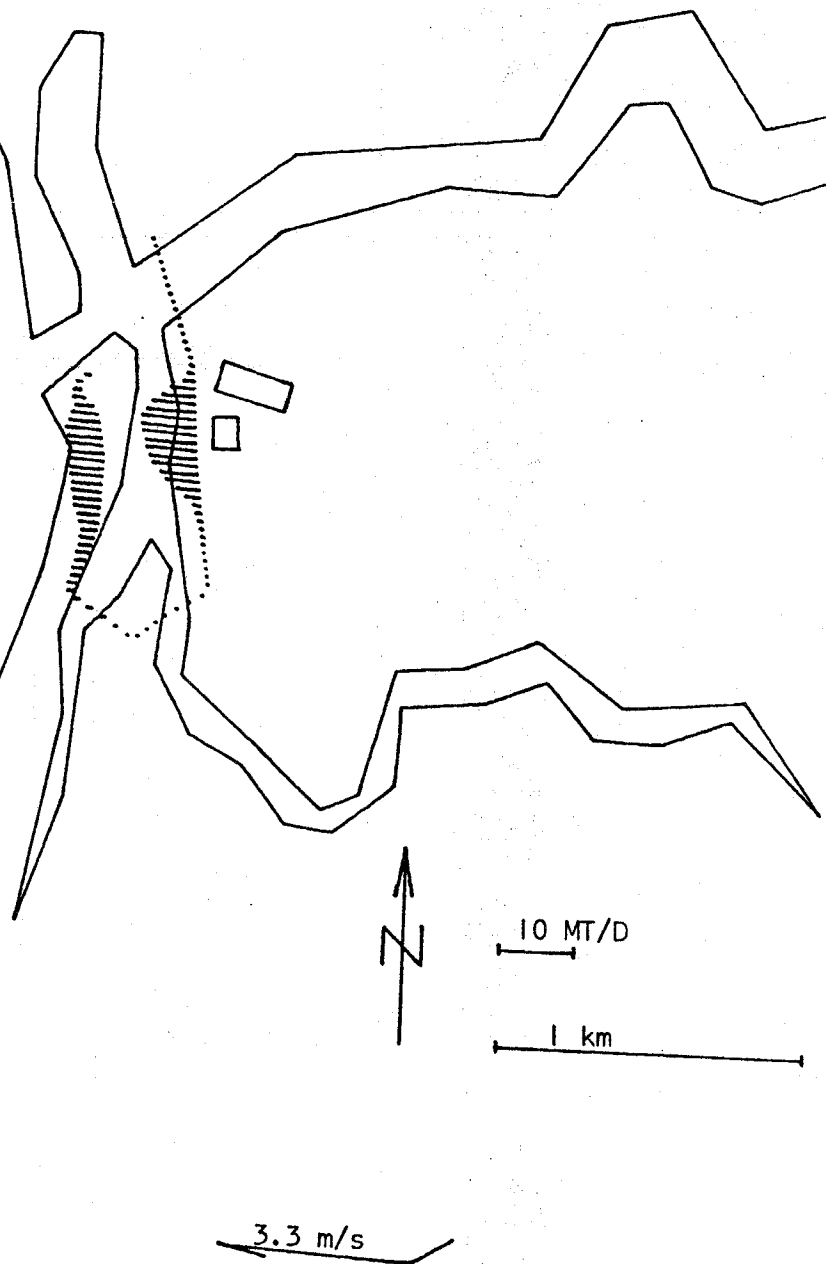
SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
11 SEPTEMBER 1974
1235-1354 PDT   EVENTS 16-19
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 15

1235

1354

10 MT/D

1 km

6.0 m/s

11 October 1974 - Haynes/Los Alamitos

A pair of flux maps present SO_2 and NO_2 remote sensor data. Four clearly identified plume measurements were made out to 17 kilometers downwind; a fifth plume crossing at a maximum distance of 37 kilometers was made also.

In Figure 16, the SO_2 plume is shown to be narrow near the source (an average of five measurements); it widens with increasing distance. No clearly defined SO_2 plume is apparent at the farthest traverse. The SO_2 mass flux calculation for the nearest traverse is 93.1 MT/D; the next two are 78.0 and 65.2 MT/D.

Figure 17 shows complementary NO_2 data with a significant difference: the NO_2 plume appears small near the source and tends to increase with downwind distance. While the far downwind NO_2 appears larger than the SO_2, the plume boundaries are still indistinct. The NO_2 mass flux calculations for the three close traverses are 21.0, 57.5, and 69.6 MT/D NO_2.

SULFUR DIOXIDE FLUX
ARB POWER PLANT STUDY
11 OCTOBER 1974
1346-1705 PDT EVENTS 18-25

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 16
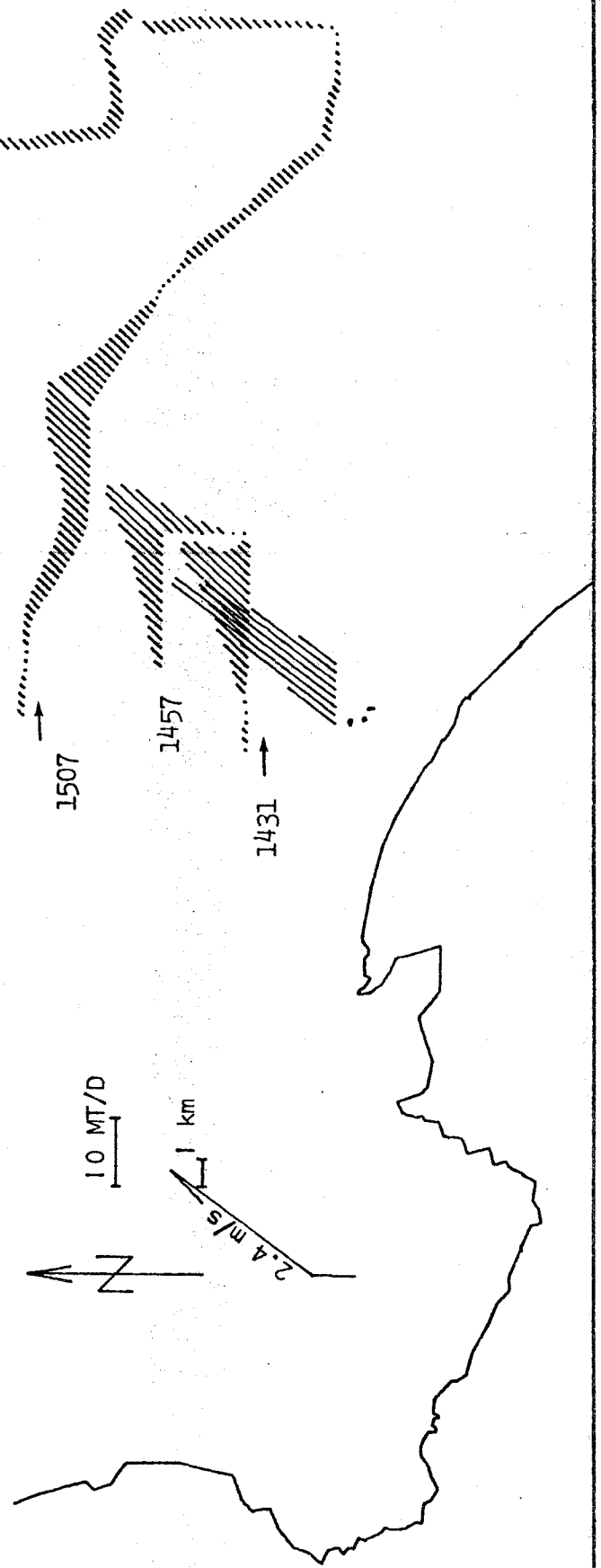
1705

1507

1457

1431

10 MT/D

1 km

2.4 m/s

N

NITROGEN DIOXIDE FLUX
ARB POWER PLANT STUDY
11 OCTOBER 1974
1346-1705 PDT EVENTS 18-25
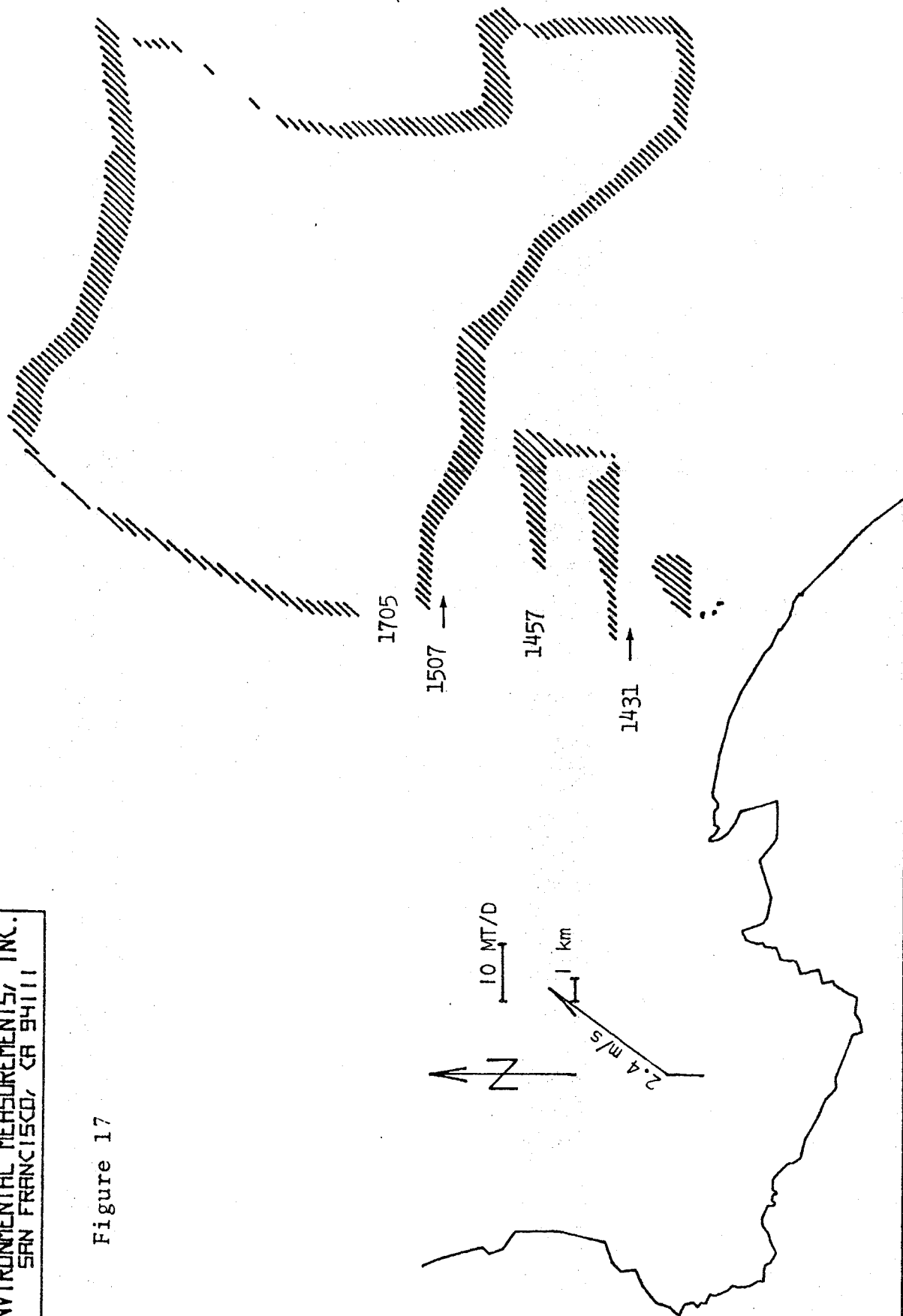
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 17

1705
1507
1457
1431

10 MT/D
1 km
2.4 m/s
N

4-12

16 October 1974-Haynes/Los Alamitos

Two sulfur dioxide maps are presented: SO_2 ground-level and SO_2 mass flux.

Figures 18 and 19 document the most easterly plume trajectory of the four measurement days in the South Coast Air Basin. The plume path is recorded on both the ground level and flux maps. The maximum ground-level SO_2 recorded during this survey is 175 ppb 10 kilometers from the sources. A distinct ground-level plume is still apparent 18 kilometers downwind.

The east leg of the survey into the Santa Ana Canyon (Cal 91) shows evidence of some SO_2 build-up at ground level.

The overhead plume is less distinct -- especially at the farther distances -- than the ground-level plume. The calculated mass flux for the three near traverses is 67.9, 57.5, and 76.7 MT.D SO_2.

SULFUR DIOXIDE GROUND
ARB POWER PLANT STUDY
16 OCTOBER 1974
1436-1636 PDT EVENTS 15-18

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 18
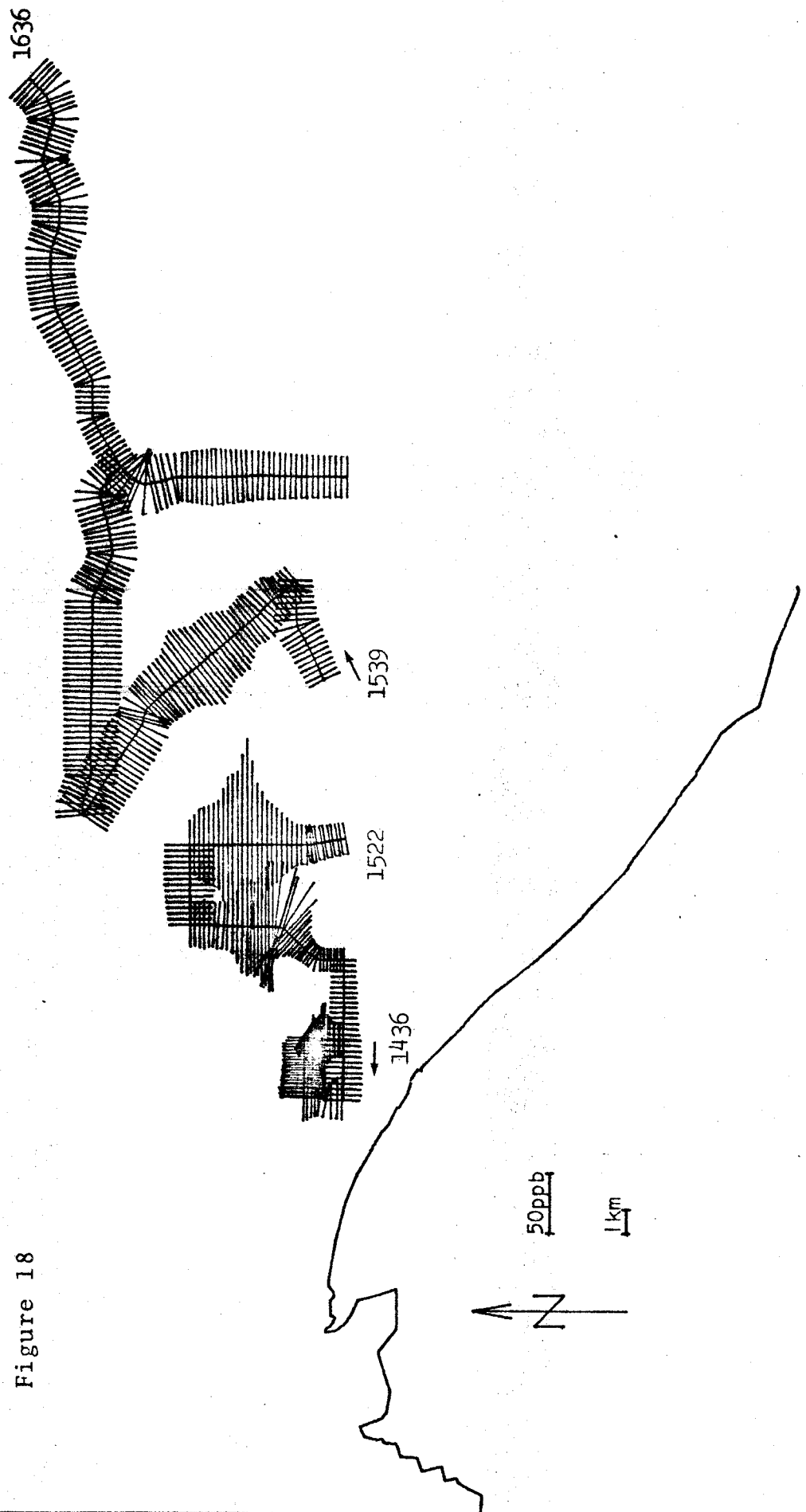
1636

1539

1522

1436

50ppb

1km

N

SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
16 OCTOBER 1974
1436-1636 PDT   EVENTS 15-18
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 19

1636

1539

1522

1436

10 MT/D

1 km

3.1 m/s

N

SULFUR DIOXIDE   GROUND
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 PDT   EVENTS 10-18

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 20

50ppb
1km

N

1150
1142
1207
1424
1559
1644

17 October 1974-Haynes/Los Alamitos

A complete set of sulfur dioxide and nitrogen oxide maps are presented.

The SO_2 maps, Figures 20 and 21, show distinct plume data at 15 kilometers with indications of plume impact out to 46 kilometers. The average mass flux for the four nearest traverses is 201.4 MT/D SO_2. The peak ground-level influence is 130 ppb SO_2, 12 kilometers from the stacks. High ground-level SO_2 concentrations (to 125 ppb) are recorded north and west of the target plants.

The complementary NO_x/NO_2 data are presented in Figures 22 and 23. The ground-level nitrogen oxides map shows high concentrations (to 250 ppb) west and north of the power plants. The NO_2 flux map again shows gas build-up downwind: 17.0, 76.5, 119.0 MT/D NO_2 (calculated at a wind speed at 3.1 M/S). Larger plume anomalies to the left of the target plants are from other stationary sources.
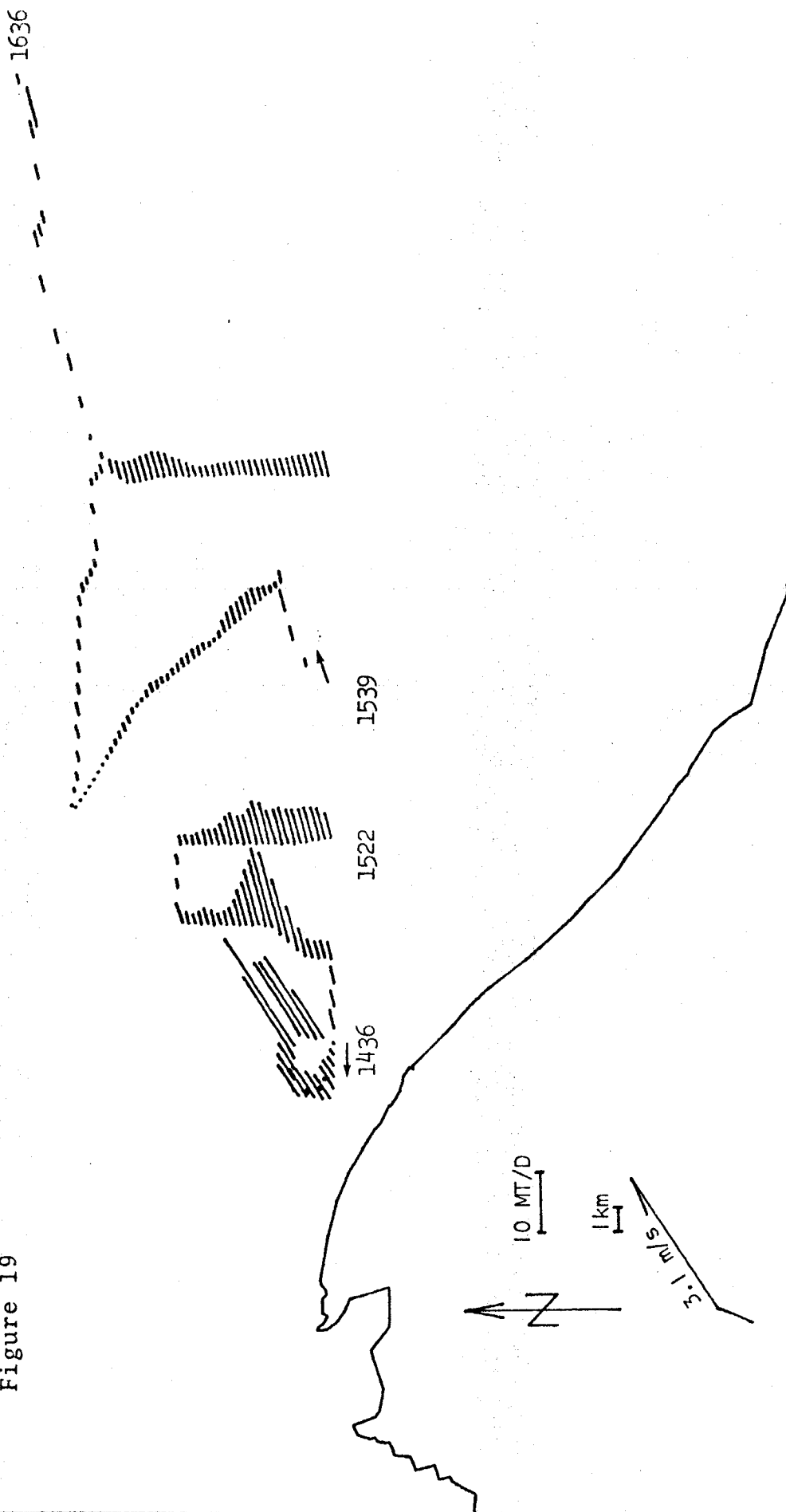
SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 PDT   EVENTS 10-18
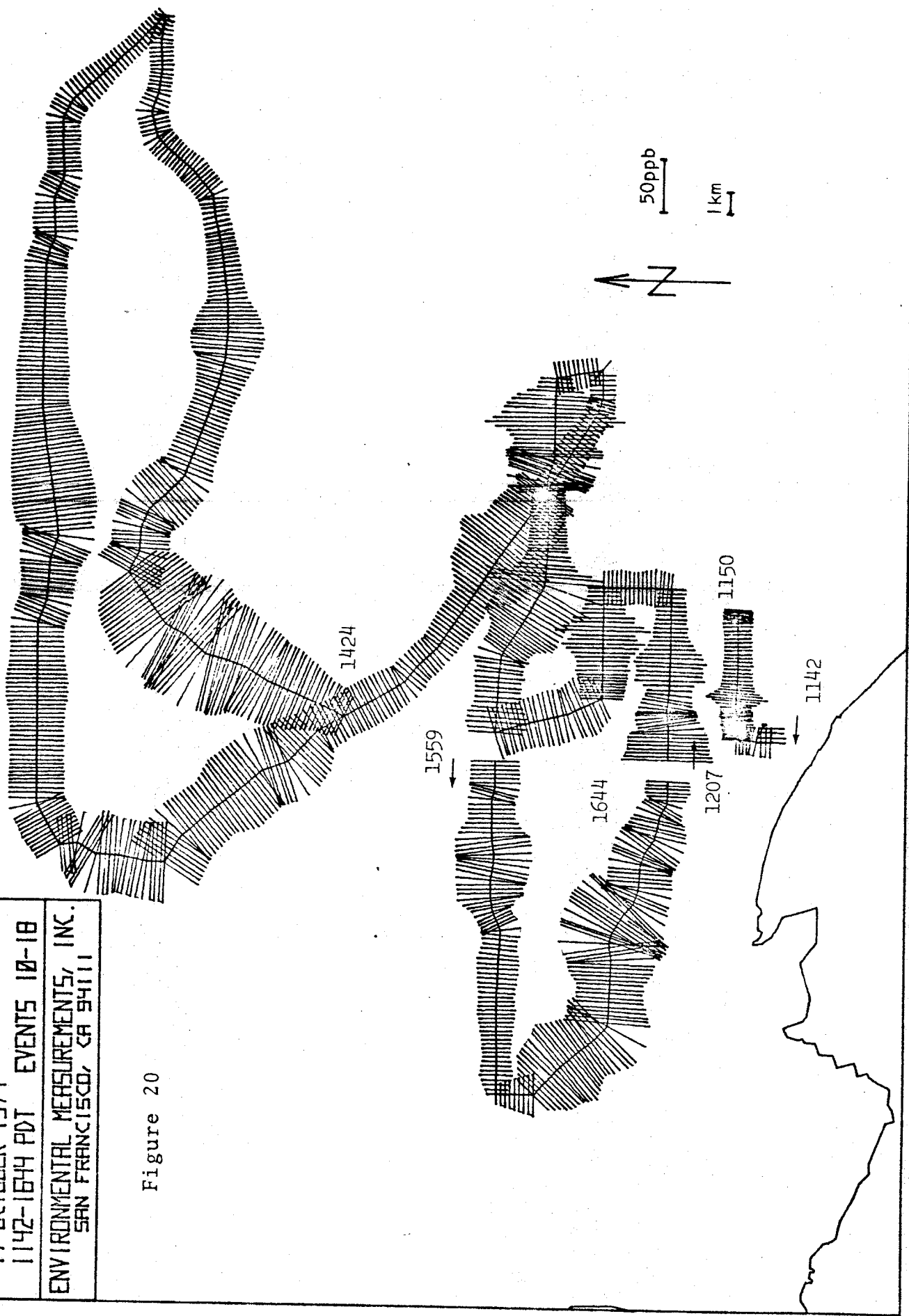
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 21

10 MT/D

1 km

3.1 m/s

N

1424

1207

1150

1142

NITROGEN OXIDES GROUND
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 PDT EVENTS 10-18

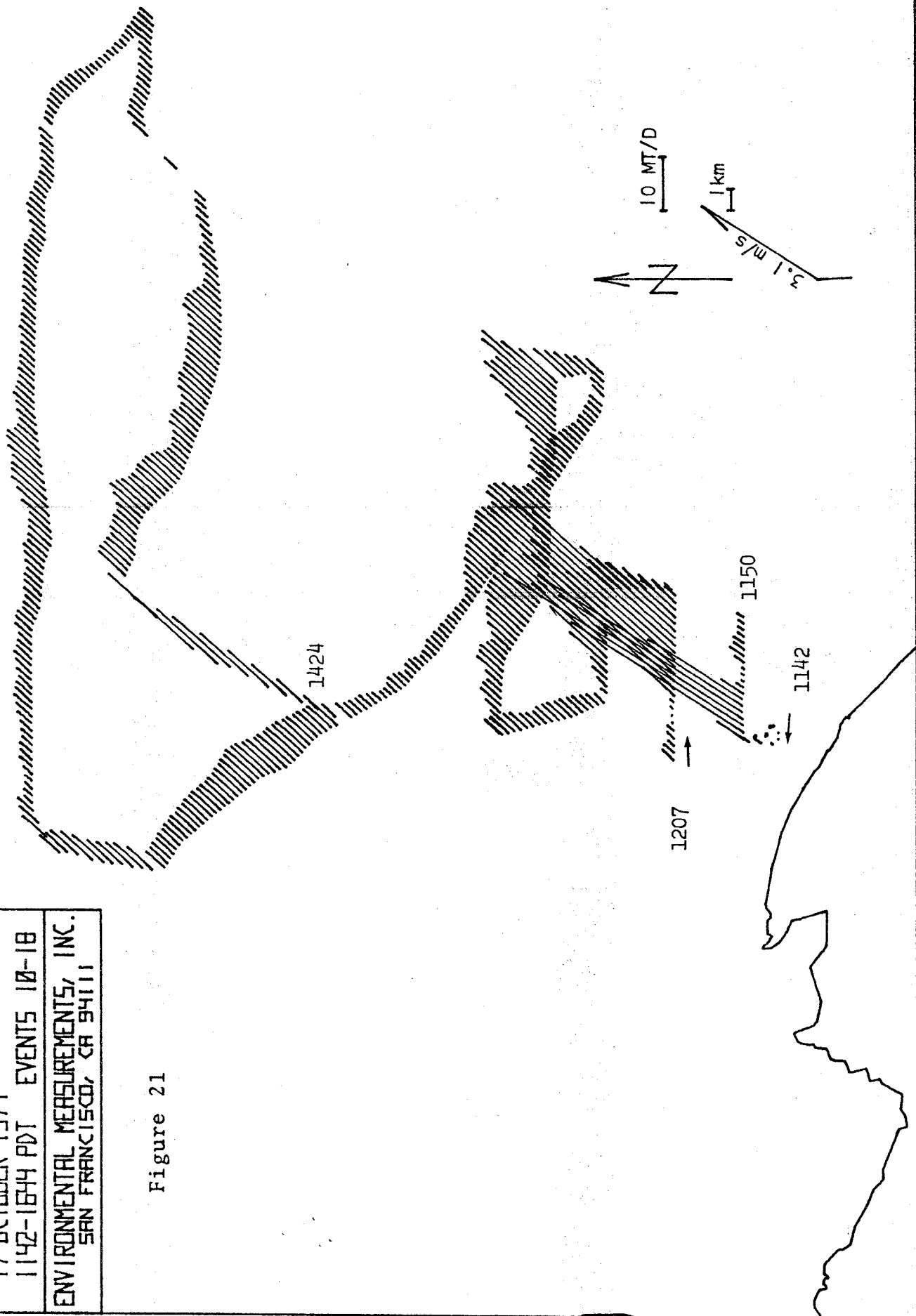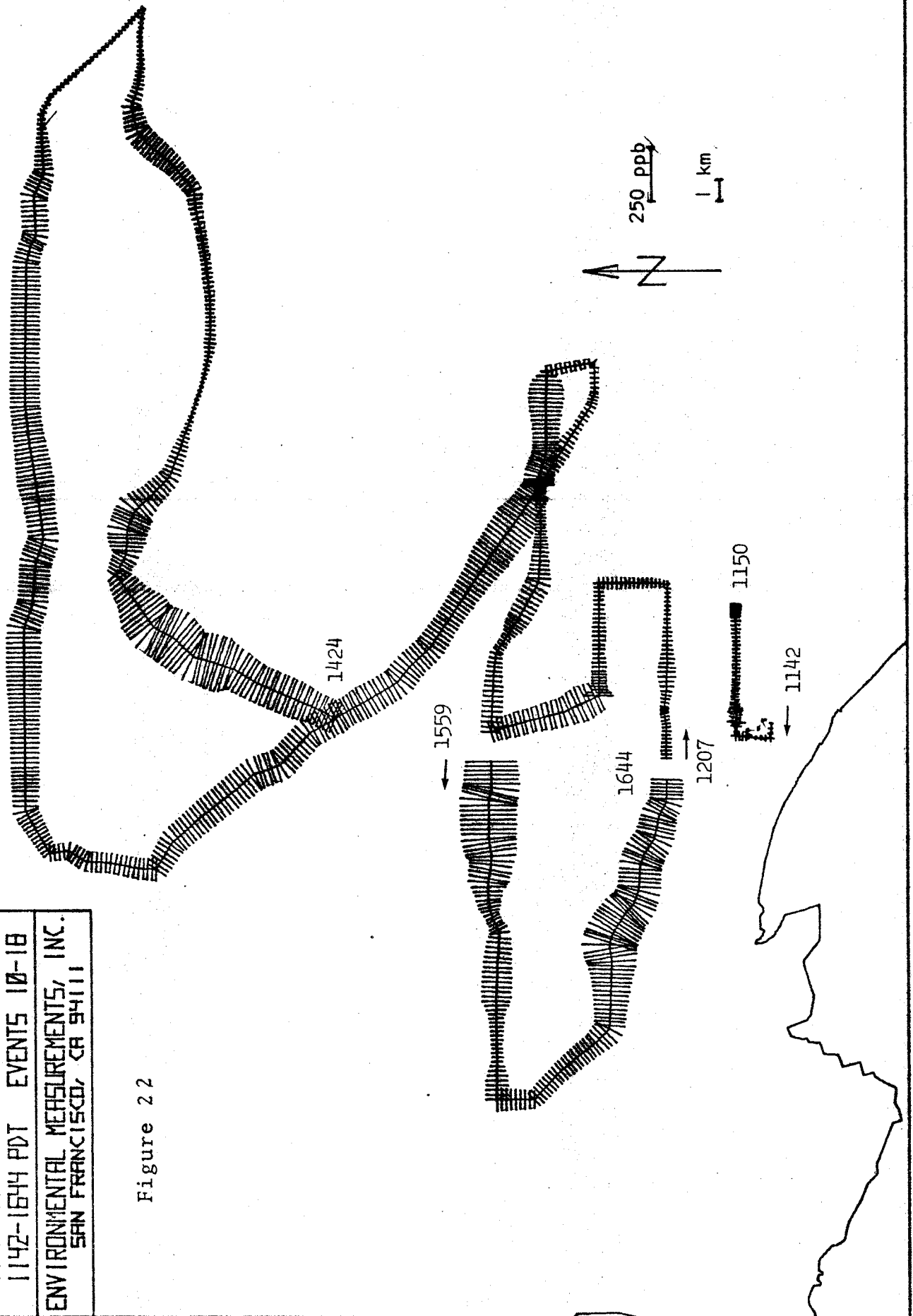ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 22

NITROGEN DIOXIDE FLUX
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 PDT EVENTS 10-18

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 23
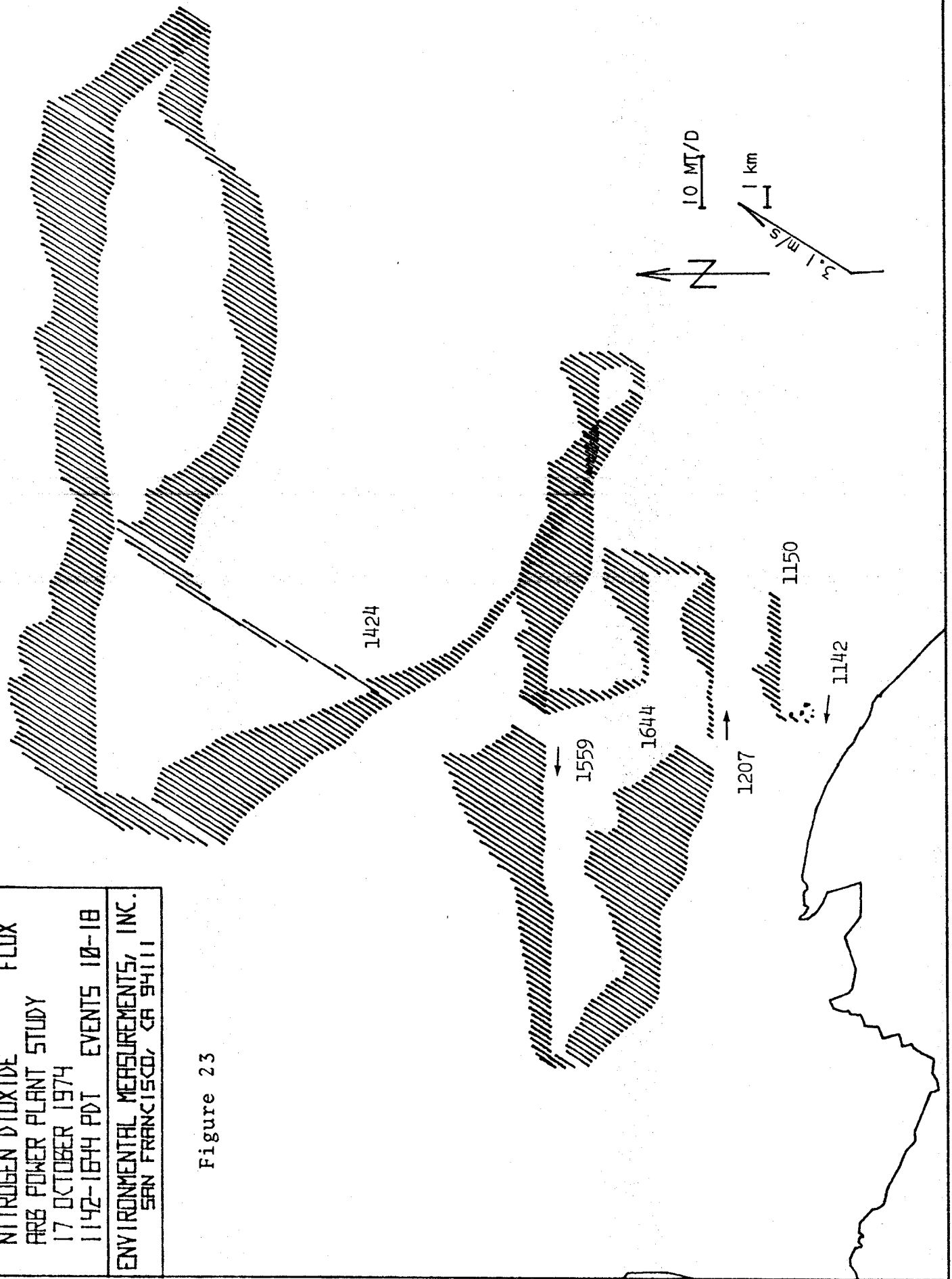
30 October 1974-Haynes/Los Alamitos

This three-map set includes two flux maps (SO_2 and NO_2) and a complementary SO_2 ground-level map.

The SO_2 maps, Figures 24 and 25, document clear plume measurements to 26 kilometers downwind. At 14 kilometers the peak SO_2 touchdown is 90 ppb. The survey continued late in the day although the ultraviolet light was unavailable for remote SO_2 measurements. Ground-level indication of SO_2 impact of the power plant plumes is evident at 46 kilometers. The average mass flux for the three traverses nearest the plants is 88.9 MT/D SO_2.

Figure 26 displays the NO_2 remote sensor measurements. This map contains further evidence that the power plant plume was detectable to a distance of 46 kilometers downwind. The first three NO_2 flux calculations are 21.5, 47.0, and 95.0 MT/D.

SULFUR DIOXIDE   GROUND
ARB POWER PLANT STUDY
30 OCTOBER 1974
1402-1621 PST EVENTS 37-43

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 24

1621

1402

50ppb

1 km

N

SULFUR DIOXIDE   FLUX
ARB POWER PLANT STUDY
30 OCTOBER 1974
1402-1621 PST   EVENTS 37-43

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 25

1515

1402

10 MT/D

1 km

4.8 m/s

NITROGEN DIOXIDE FLUX
ARB POWER PLANT STUDY
30 OCTOBER 1974
1402-1621 PST EVENTS 37-43

ENVIRONMENTAL MEASUREMENTS, INC.
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Figure 26

Section 5

ANALYSIS

Analysis of the power plant plume data has been performed. The maps presented in Section 4 are themselves an analysis. They are a step beyond reduction of the field data to engineering units; the processing by computer into flux calculations and maps are a sophisticated analysis designed to graphically communicate the results of the moving measurement surveys. But these results can be analyzed further. Several analyses are offered here, not as exhaustive treatments of air sampling data, but as examples of additional processing and modeling that can be usefully undertaken. They are:

- Plume Path Analysis: composite plume paths derived from overhead and ground-level measurements

- Ground-Level Impact: comparison of moving ground-level measurements with stationary data

- Mass Flux Analysis: remotely measured emission rates

- Trajectory Analysis: tracing remotely measured emissions back to source areas

- Axial Plume Concentrations: actual measured ground-level concentrations along plume axis

PLUME PATH ANALYSIS

The four days of reported South Coast Air Basin measurements have been reviewed to determine the path of the co-entrained Haynes/Los Alamitos plumes. From map sets for each data-day the plume boundaries were chosen from the plume anomalies recorded by both the remote sensor and point sampling instruments. These boundaries have been overlayed on maps of the study area. Figures 27, 28, 29 and 30 present the results of the plume path analysis for 11, 16, 17 and 30 October 1974.

The maps show that the combined power plant plumes had three compass angles and two plume widths. The constructed plume paths for 11 and 17 October are nearly identical. The plume widths for 16 and 30 October are similar but the angles differ.

The plume paths have not been extended beyond reasonably certain indications from the COSPEC Total Burden data and the ground-level sensor results; in some cases ground-level anomalies suggest far downwind indications of plume touchdown. But because of the ambiguity in the other results the plume path was not extended to these far downwind distances. Such plume path analyses can be used to determine horizontal dispersion coefficients for modeling purposes when sets of multiple measurements are made at each downwind radius.

Figure 27

PLUME PATH ANALYSIS
ARB POWER PLANT STUDY
11 OCTOBER 1974
1346-1705 HRS EVENTS 18-25

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

N

5-3
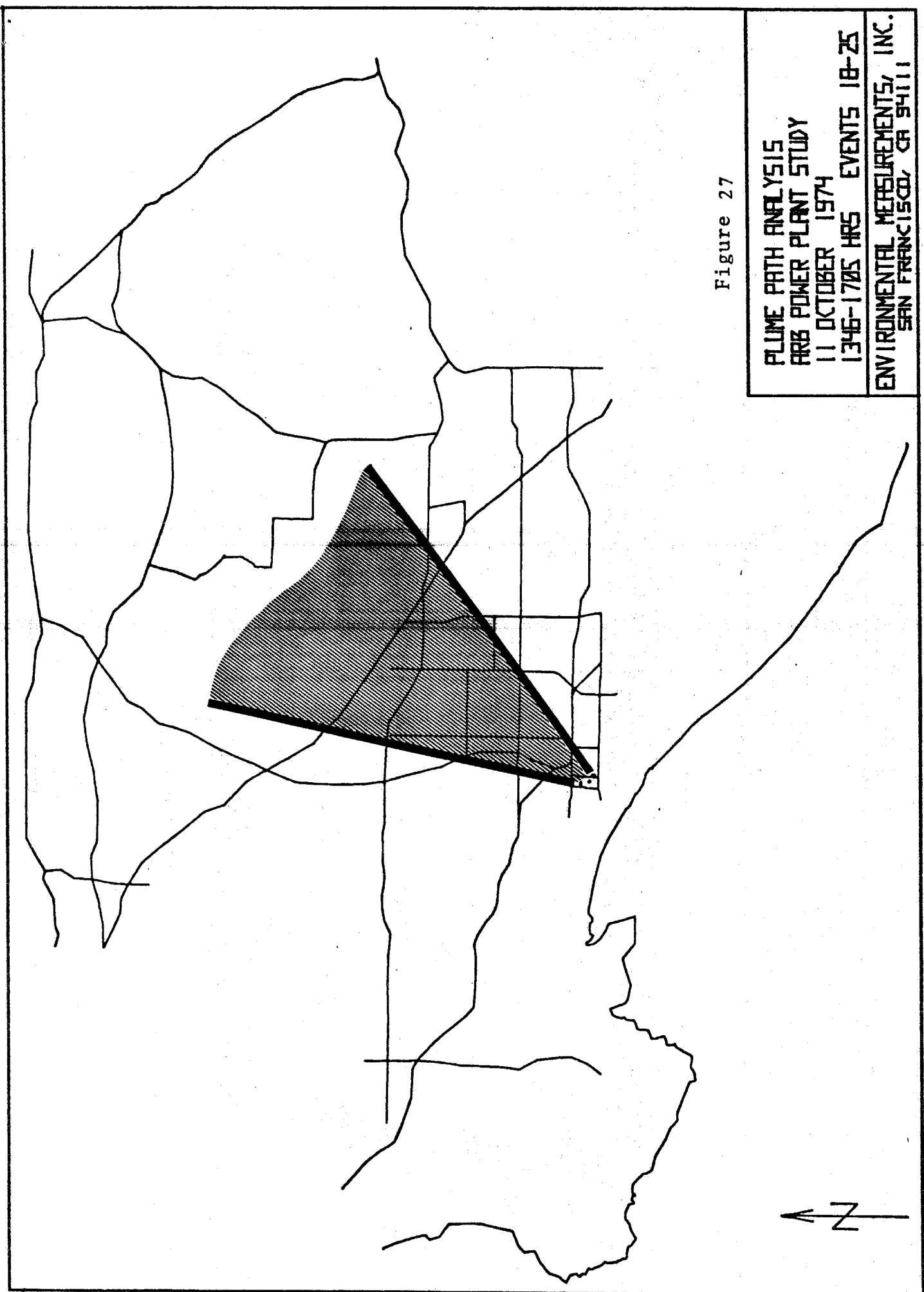
Figure 28

PLUME PATH ANALYSIS
ARB POWER PLANT STUDY
16 OCTOBER 1974
1436-1636 HRS   EVENTS 15-18

ENVIRONMENTAL MEASUREMENTS, INC
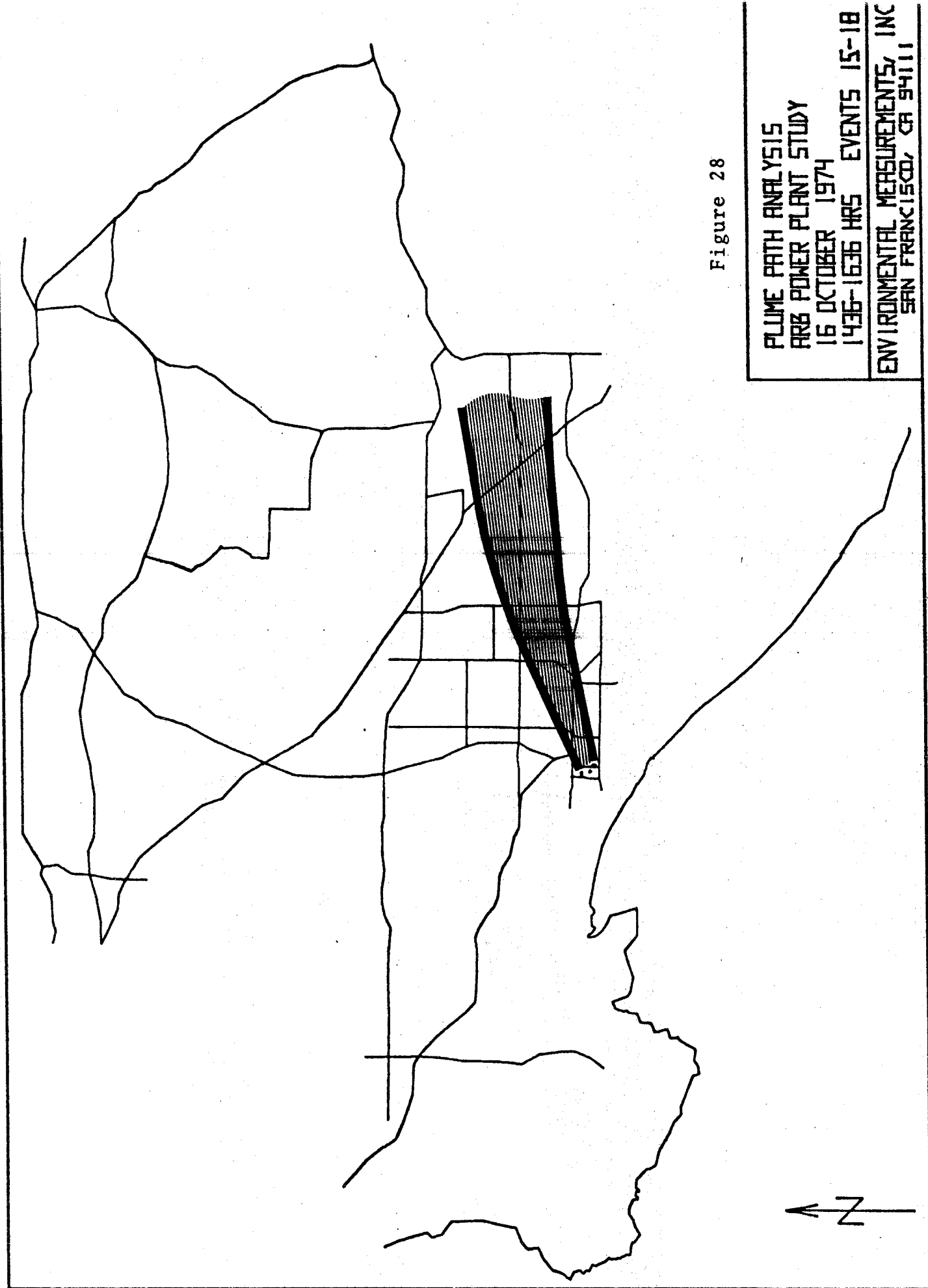SAN FRANCISCO, CA 94111

Figure 29

N

Figure 30

PLUME PATH ANALYSIS
ARB POWER PLANT STUDY
30 OCTOBER 1974
1402-1621 HRS   EVENTS 37-43

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 1111

GROUND-LEVEL IMPACT

A comparison has been made of the moving measurements of sulfur dioxide and the hourly averages reported by various air monitoring stations near the plume path for the four October 74 data-days. The findings are presented in map form: Figures 31, 32 and 33. Three ground-level SO_2 maps are shown for 16, 17 and 30 October. These are the same maps appearing in Section 4; however, data have been added. Histogram plots of the hourly average SO_2 recorded by selected air monitoring stations are superimposed on the moving measurement data. A total of six hours of stationary data are presented. The stations are located by dots and are identified by name. The small individual plots are scaled to the same 50 ppb SO_2 per centimeter as are the moving measurement results. At the base of each plot is a bar signifying the time period during which the moving survey was conducted.

A review of these comparative data show that the combined plume from the target power plants can be related directly to elevated SO_2 measurements at the monitoring stations. A one-for-one comparison cannot be made between the essentially instaneous moving measurements of SO_2 by the AQML, and the hourly average reported for the six stations;(an analysis of this relationship is under investigation by EMI in another program). However, the readings above background can be traced to the target sources through the "bridge" provided

SULFUR DIOXIDE · · GROUND
ARB POWER PLANT STUDY
16 OCTOBER 1974
1436-1636 PDT EVENTS 15-18

ENVIRONMENTAL MEASUREMENTS, INC.
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Figure 31

Anaheim

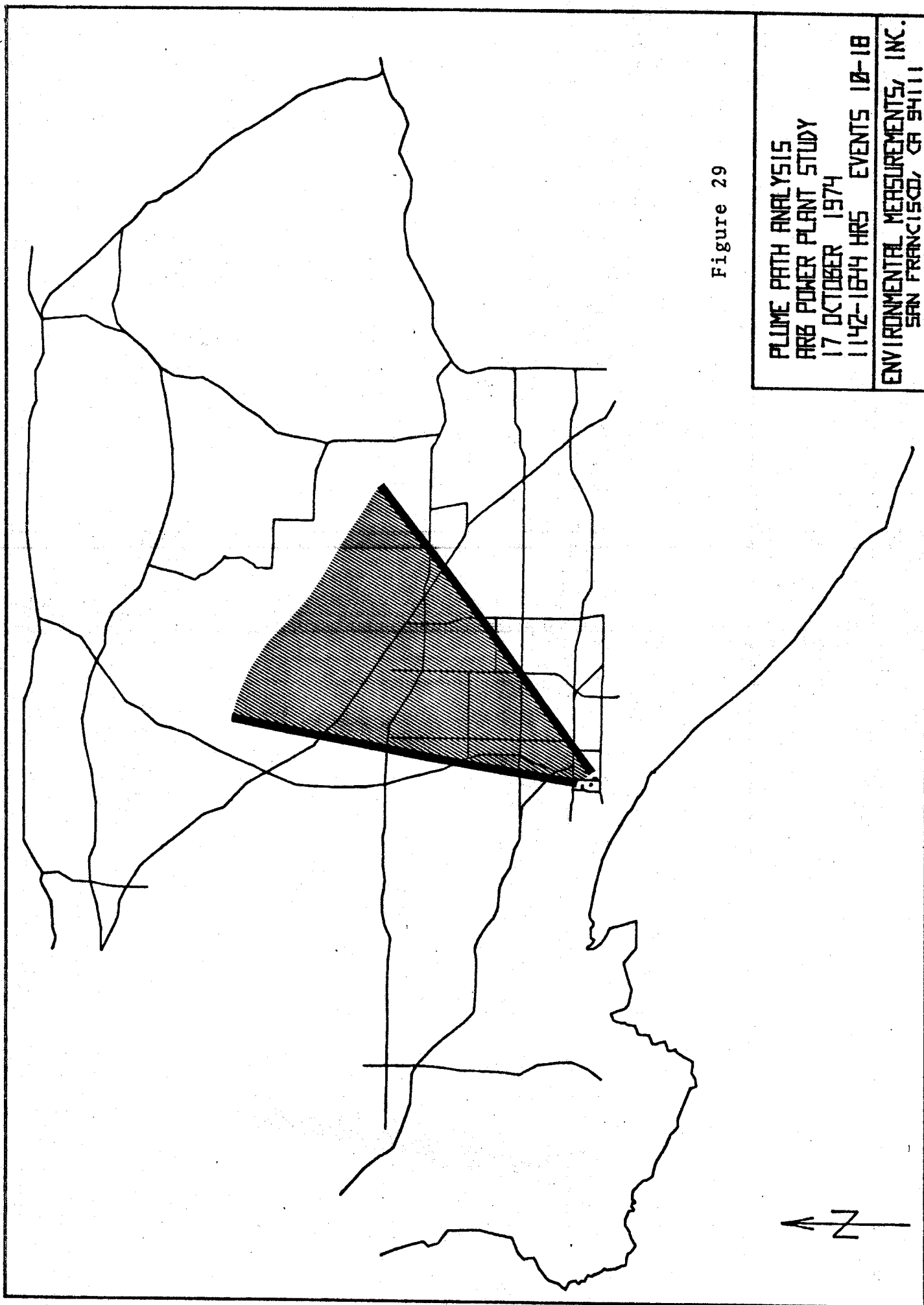La Habra

Whittler

Los Alamitos

Long Beach

50ppb

1km

N

SULFUR DIOXIDE   GROUND
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 PDT   EVENTS 10-18

ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 32

Pomona

Azusa

50ppb

1km

N

La Habra

Anaheim

Whittier

Los Alamitos

Lynwood

Los Angeles

Long Beach

SULFUR DIOXIDE   GROUND
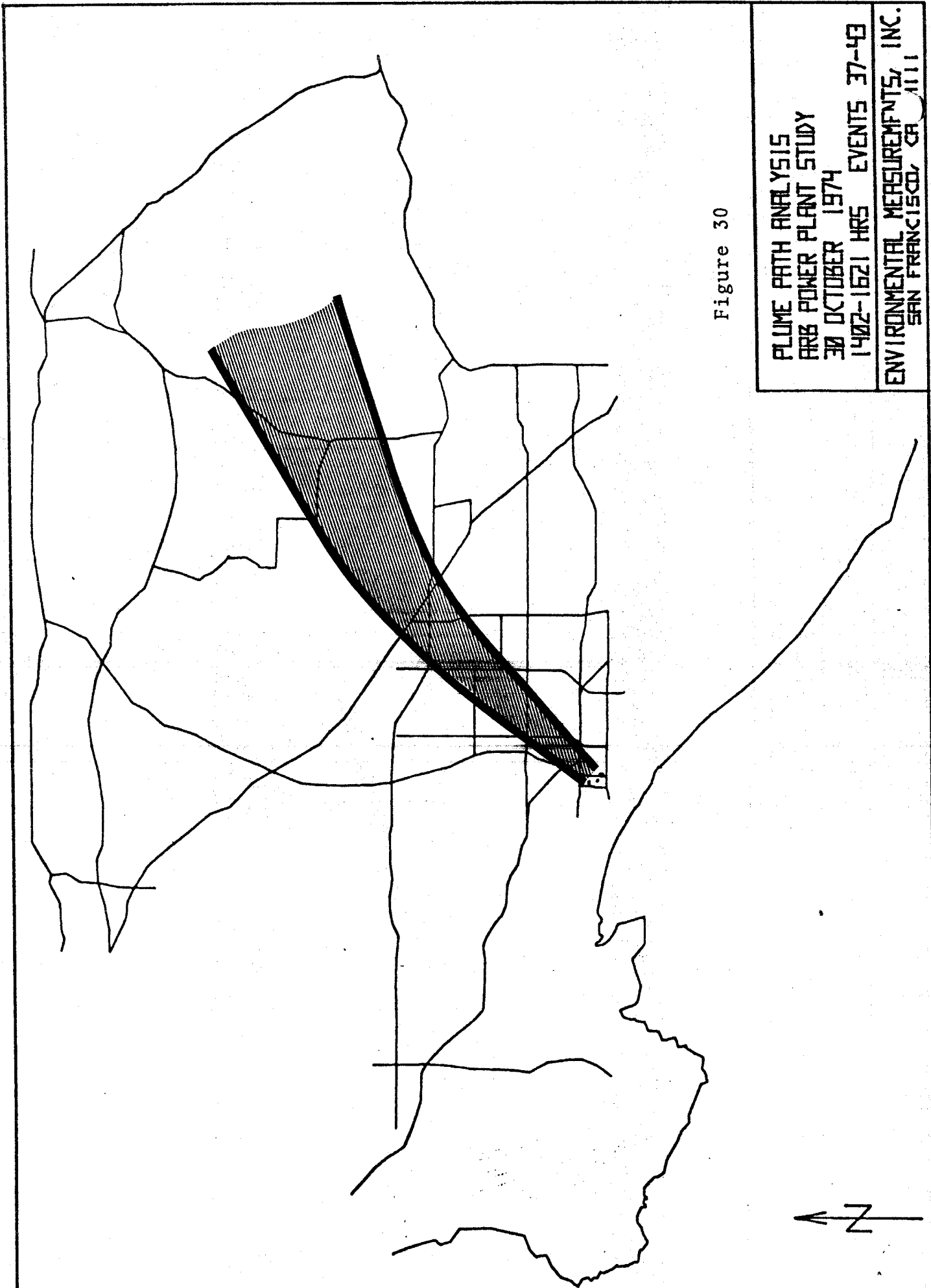ARB POWER PLANT STUDY
30 OCTOBER 1974
1402-1621 PST   EVENTS 37-43
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Pomona

Azusa
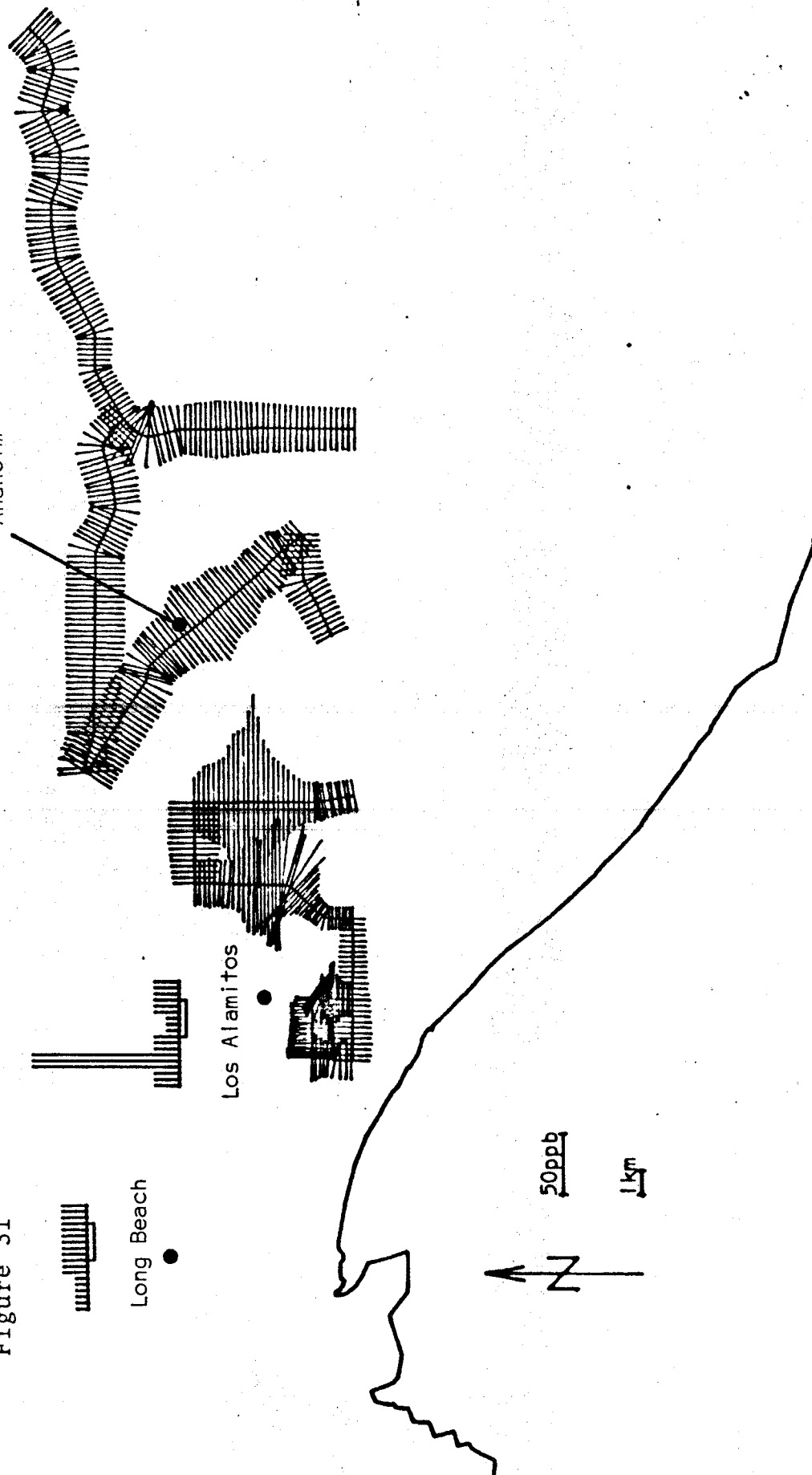
La Habra

Whittier

Los Alamitos

Long Beach

50ppb

1 km

N
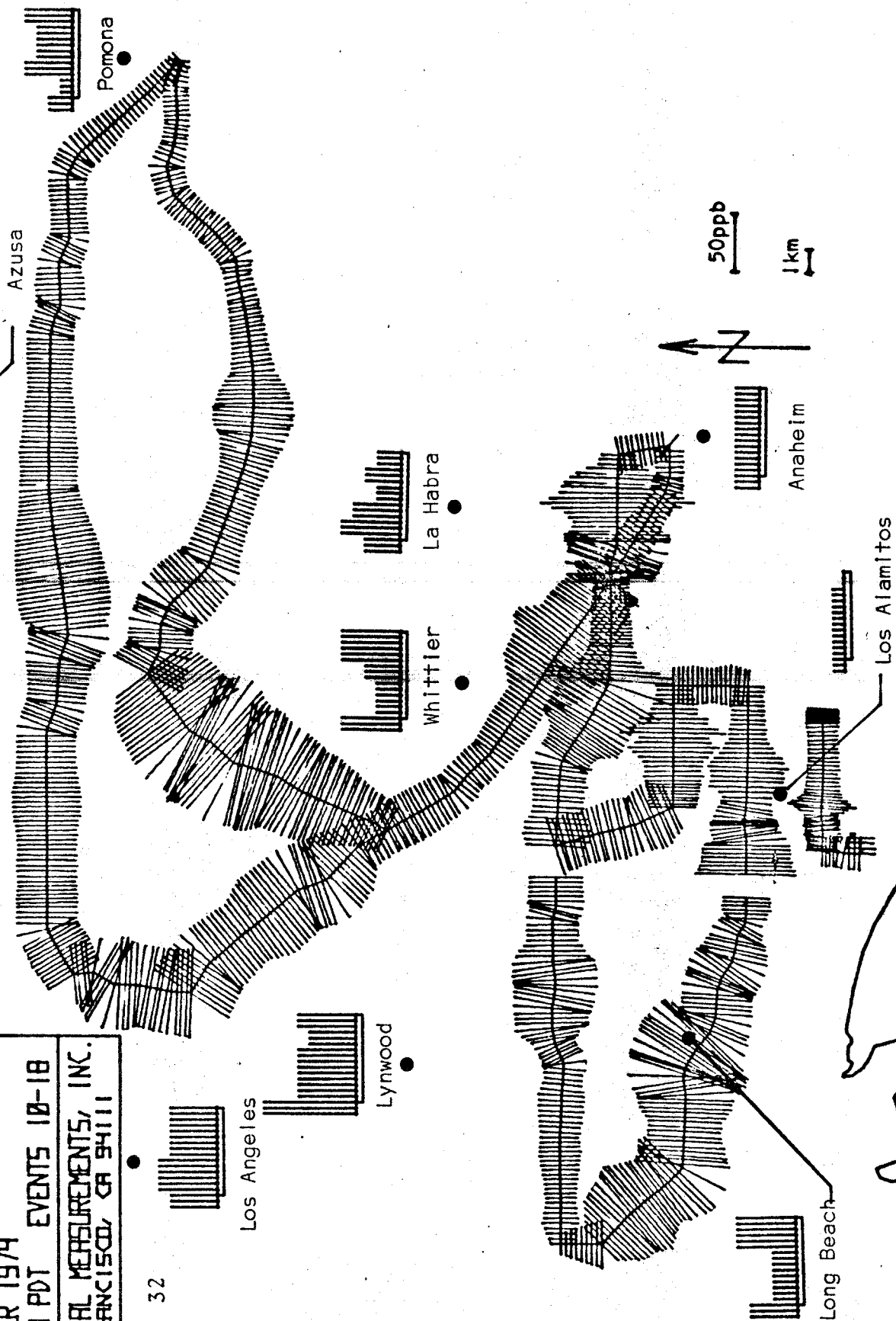
Figure 33

by the moving measurements. Examples:

- 16 Oct 74 -- The Los Alamitos 120 ppb SO_2 peak and the 50 ppb SO_2 peak at Anaheim are probably plume-related.

- 17 Oct 74 -- The La Habra, Whittier peaks (to 50 ppb SO_2) are plume-related. Peaks at Lynwood, Long Beach, and Azusa (to 80 ppb SO_2) are related to other sources.

- 30 Oct 74 -- The Los Alamitos peak of 70 ppb SO_2 is plume-related.

(None of these concentrations represent violations of air quality standards.)

This finding is important because it demonstrates that a method is available to correlate stationary source emissions with ground-level ambient air quality. Attempts to trace elevated ground-level concentrations back to a specific source or group of sources based on wind flows or other generalized wind information are less reliable -- especially at great distances -- because of the lack of detailed data. The moving laboratory, however, provides the "bridge" between the source emissions and the ground-level air quality.

The remote sensing COSPEC instrument is the key to this analysis. A moving laboratory with only a point sampling instrument could be used to monitor downwind of stationary sources and provide gradient data between stations. However, an extremely complex set of meteorological information would be needed to say which station was being influenced by a source.

But, the addition of the remote sensor in the moving laboratory provides a means of actively tracing a source plume. The peak COSPEC readings from a set of traverses locate the geographic position of the plume axis. The one percent limits of the plume anomalies determine the plume width. By knowing the location of the plume centerline and the plume width, the plume path can be determined. It is this remotely sensed plume path that can then be related to ambient air quality data collected in the stationary mode.

MASS FLUX

The primary objective of this study was to provide data on plume path and ground-level impact. A bi-product of the computer mapping process is the computation of mass flux for each plume cross section. Therefore, these mass flux numbers have been extracted from the computer analyses and are summarized in Tables III, IV and V.

SO_2 Flux - Moss Landing. The SO_2 flux calculations for 10 and 11 September are summarized in Table III. For each day there is a large number of morning measurements (7 and 10, respectively) which were averaged before calculating mass flux. These average calculations are a more accurate estimate of emission rates than those from a single measurement of the plume. All flux calculations are subject to the limitations of the wind speed data (See Section 3).

The first two average flux values for 10 September (47.1, 87.7 MT/D SO_2) differ significantly. The first is within 6% of the 49.3 MT/D measured by the ARB stack sampling crew (as derived from Source Test Report No. C4-028, Table 1, page 12). The second average calculation is 78% higher than the ARB figure. The flux map (See Figure 12) shows a much broader, second plume; this suggests a lower wind speed and/or gustier wind conditions. Thus the 1.8 M/S wind speed is probably too high; it was used because no other data were available for the time of these measurements.

Table III

SO$_2$ Mass Flux Summary

Moss Landing

Date	Event	Time (PDT)	Distance (km)	Wind Speed (m/s)	Number of Observations	SO$_2$ Flux (MT/D)
10 Sep 74	5-11	1056-1126	0.1	1.8	7	47.1
	12-18	1126-1215	0.1	1.8	7	87.7
	30-34	1453-1556	1.5	6.0	1	58.0
	"	"	5.0	6.0	1	159.6*
	"	"	8.0	6.0	1	377.3*
	"	"	11.0	6.0	1	489.3*
11 Sep 74	2-12	0919-1032	0.1	3.3	10	85.8
	"	"	0.4	3.3	10	79.0
	16-19	1235-1354	0.8	6.0	2	44.2
	"	"	5.5	6.0	2	86.0
	"	"	9.0	6.0	2	47.2
	"	"	16.0	6.0	1	62.2

* These high valves are invalid calculations resulting from distortions in the plume trajectory. See Text, Pgs. 5-15.

The four measurements reported for the afternoon of
10 September show wide variations in calculated flux. The
58.0 MT/D SO_2 measured 1.5 kilometers from the stack is with-
in 18% of the ARB-measured 49.3 MT.D, an average emission rate
for the afternoon. However, the next three numbers range up
to 489.3 MT/D. The wind conditions during Events 30-34 were
steady, but with considerable horizontal turbulence. This
condition can lead to erroneous, high flux values because the
data processing procedure assumes that the plume crosses the
road axially from the stack. When the plume path is non-axial
(as is likely for these events) the flux calculations give
high values due to both artificially increased plume widths
and wind/road angles.

Also to be considered is the effect turbulence has on the
horizontal differences in plume concentrations. During this
period ten plume crossings were made; each one was different
from the others, and some were near the noise level of the re-
mote sensor. The high fluxes reported for 10 September were
derived from the high burden measurements; low, near-zero Bur-
dens were not calculated or reported. The average of all ten
measurements would be significantly lower than the three re-
ported values.

A comparison of EMI's SO_2 burden data and results of MRI
aircraft measurements corroborates the burden results. For a
plume measurement 8 km (5 miles) from the stacks the average

SO_2 measured at the center of the plume for a depth of 350 meters (800 to 1650 feet altitude) was 0.505 ppm (derived from preliminary MRI data). The Burden (concentration x distance) result is 177 ppmM SO_2 (0.505 x 350). This is within 18% of a nearby COSPEC measurement (Event 30 for 10 Sep) where the peak SO_2 Burden was 216 ppmM SO_2. This close agreement supports the hypotheses that the Burden measurements are accurate and the high fluxes for this period are a function of wind conditions.

The morning measurements near the stacks on 11 September average 82.4 MT/D SO_2. This is 47% higher than the 56.1 MT/D measured later the same day by the ARB.

SO_2 Flux-Haynes/Los Alamitos. The SO_2 mass flux summary in Table IV presents calculations for the Haynes/Los Alamitos power plant for 11, 16, 17 and 30 October 1974. These emissions rates are for the combined plumes of both plants. Some near and between plant traverses were made to separately quantify the two plants. But these data have not been processed; only combined plume data are presented.

For comparison, the average SO_2 emissions were calculated from the data gathered by the LAAPCD (Reports for Contract No. 4-286). The total SO_2 for Haynes Units 4, 5 and 6 is 38.9 MT/D; the total for Los Alamitos Units 5 and 6 is 48.7 MT/D. The sum of these, 87.6 MT/D, is taken as a nominal, minimum emission rate to compare with the COSPEC results.

Table IV

SO$_2$ Mass Flux Summary

Haynes/Los Alamitos

Date	Events	Time	Distance (km)	Wind Speed (m/s)	Number of Observations	SO$_2$ Flux (MT/D)
11 Oct 74	18-25	(PDT) 1346-1705	1.5	2.4	5	93.1
	"	"	6.0	2.4	1	78.0
	"	"	9.5	2.4	1	65.2
	"	"	14.0	2.4	1	138.2
16 Oct 74	15-18	(PDT) 1436-1636	2.0	3.1	1	67.9
	"	"	6.5	3.1	1	57.5
	"	"	10.0	3.1	1	76.7
17 Oct 74	10-18	(PDT) 1142-1644	1.5	3.3	1	242.2
	"	"	6.0	3.1	1	344.6
	"	"	9.5	3.1	1	163.7
	"	"	12.0	3.1	1	167.2
	"	"	15.0	3.1	1	89.4
30 Oct 74	37-43	(PST) 1402-1621	2.0	4.8	1	64.9
	"	"	15.0	4.8	1	143.8
	"	"	26.0	4.8	1	58.0

For three days (11, 16, 30 October) the calculated fluxes average 84.3 MT/D SO_2, within 6% of the nominal. For 17 October the fluxes are larger. The close-in flux is three times the average for the other three days; a reduction of flux is seen sownwind. It is unlikely that the wind speed is high by a factor of three; it is possible that for this day the combined $SO2$ emissions for the two plants were significantly greater than the other three days. The decay in SO_2 flux downwind has been documented for other power plants.

NO_2 Flux-Haynes/Los Alamitos. Some NO_2 mass flux calculations have been performed for the Haynes/Los Alamitos plants. They are presented in Table V.

The table lists three sets of calculations for 11, 17 and 30 October. A consistent pattern emerges: a low value of about 20 MT/D NO_2 is computed for traverses within 2 kilometers of the plants and the flux increases significantly downwind. It can be estimated from these results that the conversion rate of NO to NO_2 within the plume is 1-2% per minute. Data of this type are useful for constructing and validating plume models which include mechanisms for the conversion of NO to NO_2.

Table V

NO$_2$ Mass Flux Summary

Haynes/Los/Alamitos

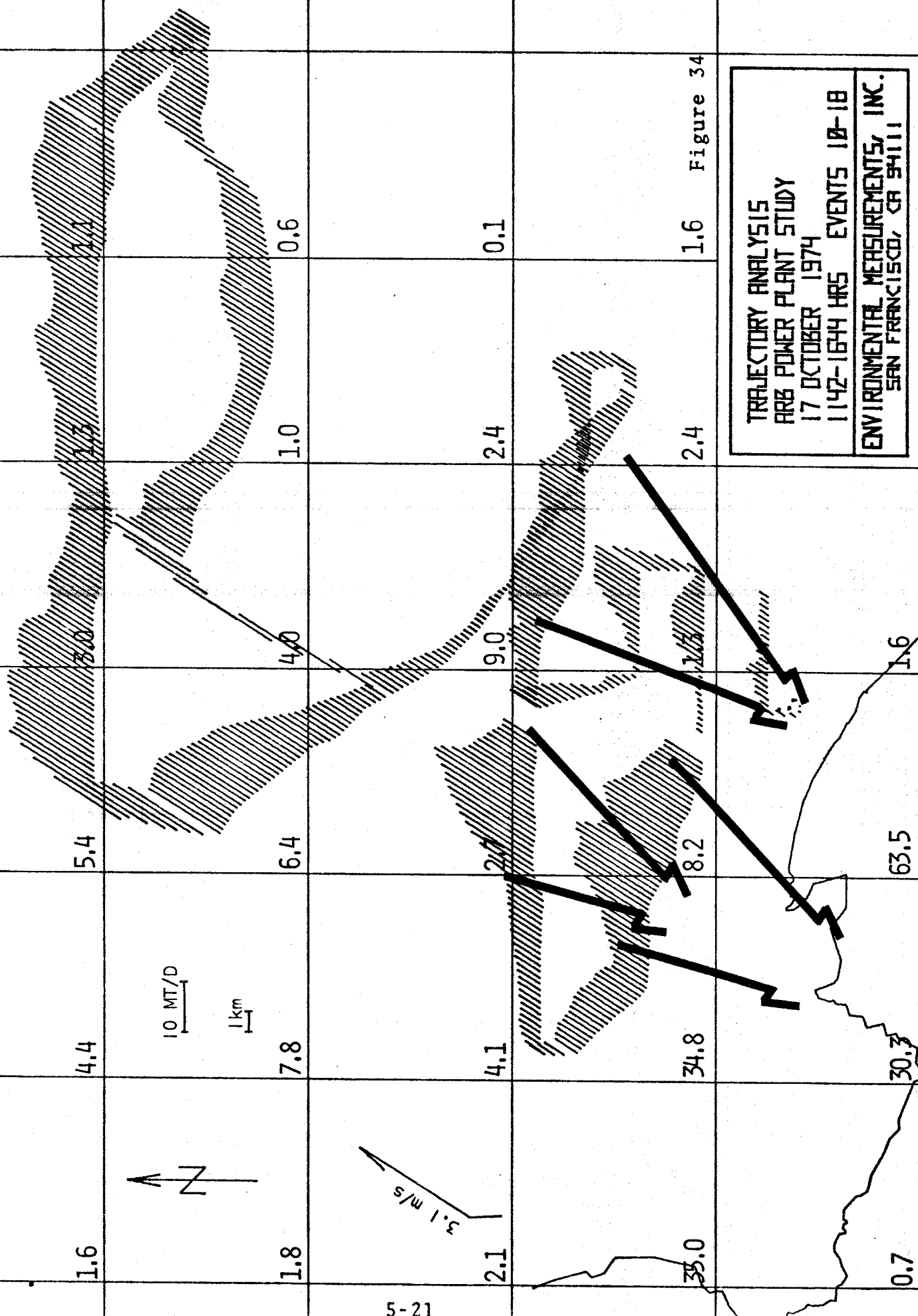| Date	Event	Time	Distance (km)	Wind Speed (m/s)	Number of Observations	NO$_2$ Flux (MT/D)
11 Oct 74	18-25	(PDT) 1346-1705	1.5	2.4	5	21.0
	"	"	6.0	2.4	1	57.5
	"	"	9.5	2.4	1	69.5
	"	"	14.0	2.4	1	54.5
17 Oct 74	10-18	(PDT) 1142-1644	1.5	3.3	1	17.0
	"	"	6.0	3.1	1	76.5
	"	"	9.5	3.1	1	119.0
	"	"	12.0	3.1	1	108.0
30 Oct 74	37-43	(PST) 1402-1621	2.0	4.8	1	21.5
	"	"	15.0	4.8	1	47.0
	"	"	26.0	4.8	1	95.0

TRAJECTORY ANALYSIS

One function of the flux map is to provide a tool for tracing emissions back to the source. The NO_2 flux map for 17 October 74 has been treated in a special way (Figure 34) to illustrate this technique. The approximate boundaries for three significant NO_2 plumes have been added to the map. The plume boundaries are arrow-shaped, to represent the vectoring of the remotely measured emissions back toward their origin.

Also added to the map is the 10 kilometer x 10 kilometer grid used by KVB, Inc. (KVB Report No. 5800-179) for their NO_x emissions inventory of the South Coast Air Basin. In each square is the notation of NO_x emissions in tons/day (from Figure 9-3, page 9-16 of the KVB Report).

The trajectory for the target power plants constitutes a known quantity in this analysis. The vector is directed back toward the square labeled "63.5". This is a square in which the two power plants used in the study are located. The two trajectories to the west are unknowns. Applying the plume geometry derived from the known Haynes/Los Alamitos plume to the two large NO_2 anomalies north of Long Beach, produces vectors back to the squares labeled "34.8" and "30.3". This is not a detailed analysis but does suggest that remote sensing plume measurements can be traced back to the source and that they can provide a means for testing emission inventories gathered by other methods.

TRAJECTORY ANALYSIS
ARB POWER PLANT STUDY
17 OCTOBER 1974
1142-1644 HRS   EVENTS 1B-1B
ENVIRONMENTAL MEASUREMENTS, INC.
SAN FRANCISCO, CA 94111

Figure 34

5-21

AXIAL PLUME CONCENTRATIONS

In the late afternoon of 17 October 74, there was an opportunity to traverse the axis of the target plumes. The wind was from the south; the plumes were transported north along I-605. These conditions permitted the direct measurement of SO_2 and NO_x ground-level concentrations on a near-axial path along the plume. The AQML route varied only 1.5 km from the apparent axis throughout the 15 km traverse. The results are presented in Figure 35.

Both SO_2 and NO_x profiles peak at 8-9 km from the sources. (The plume is assumed to be the co-entrained plumes from the two target plants; the zero distance is taken as a point midway between the plants.) The depression in the SO_2 profile at 4-7 km corresponds to the 1.5 km variance from the plume centerline caused by the shape of the road. The NO_x curve is a distinct anomaly despite the presence of vehicular NO_x along the freeway.

Comparison of these measured results with modeled results (predictions) of ground-level axial concentrations can be used to validate site-specific plume models.

Figure 35

SO$_2$/NO$_x$ Axial Ground-Level Concentrations

Haynes/Los Alamitos Power Plants

17 October 1974 1711-1727 PDT
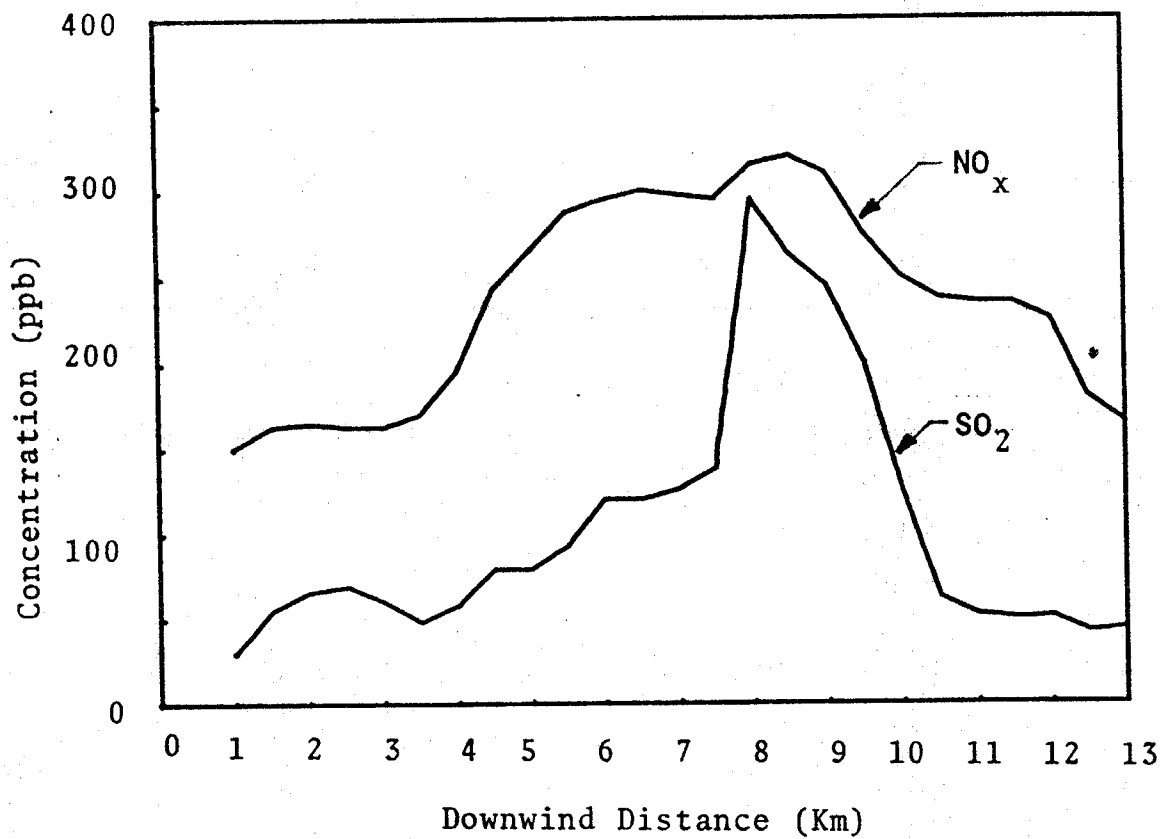
GLOSSARY

AGC -   Automatic Gain Control, the light sensing circuit of the correlation spectrometer

AQML -   Air Quality Moving Laboratory, an array of instruments designed to monitor air pollutants in a truly mobile mode

Burden -   Vertically integrated concentration-path length measurements of pollutants as measured by the Correlation Spectrometer, (also overhead burden, total burden)

COSPEC -   Correlation Spectrometer, manufactured by Barringer Research Ltd., an electro-optical remote sensor which monitors pollutants along light paths originating from natural or artificial radiation

Data Day -   A measurement day when personnel and equipment are mobilized to survey air quality; actual hours of measurement may range from one to twenty-four depending on conditions at the site

Event -   A single measurement by the moving laboratory; a plume crossing or a regional survey; may vary in length from one minute to one hour

Flux -   See Mass Flux

Ground Level -   Ground-level concentrations of pollutants as measured by point monitors

Km -   Kilometers

MT/D -   Metric Tons per day, emission rate

ppb -   Parts per billion, concentration measurement

ppmM -   Parts per million-meters, concentration-path length measurement

Mass Flux -   Emission rate of pollutant across a traverse
                  route calculated from remote sensing data
                  (also mass flow rate)

Noise -   Spectrometer response due to spurious, unwanted
                  electronic signals; usually a few ppmM depend-
                  ing on gas measured and available light

Overhead Burden -See Burden

Pibal -   Pilot balloon, used to measure wind speed and
                  wind direction at the elevation of the plume
                  (stack emissions)

Plume -   Dispersing stack emissions

Total Burden -   See Burden

TB -   See Burden

Ground -   See Ground-level

GL   See Ground-level

RMS Error -   Root Mean Square Error

Traverse -   A moving measurement using a moving laboratory;
                  a traverse route is a highway or road travelled
                  during a survey

UTM -   Universal Transverse Mercator coordinates used
                  on U.S. Geological Survey Topographic Maps

Mass Flux Calculation column headings

    (Page 3-10, Figure 10)

      BRING   =   Bearing of moving laboratory, in degrees

      R   =   Wind/Road Angle, the difference between the wind direction and bearing, in degrees

      S   =   Segment of road along which mass flux is being calculated, in meters

      AVZ   =   Average Z, the average remote sensor reading, in ppmM

      Sin (R) =   Sine of Wind/Road angle

      Flow   =   Flow rate or Mass Flux, in metric tons (SO_2/NO_2) per day

      SUM   =   Cummulative totals of mass flux, in metric tons per day